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BRITISH JOURNAL OF INDUSTRIAL MEDICINE

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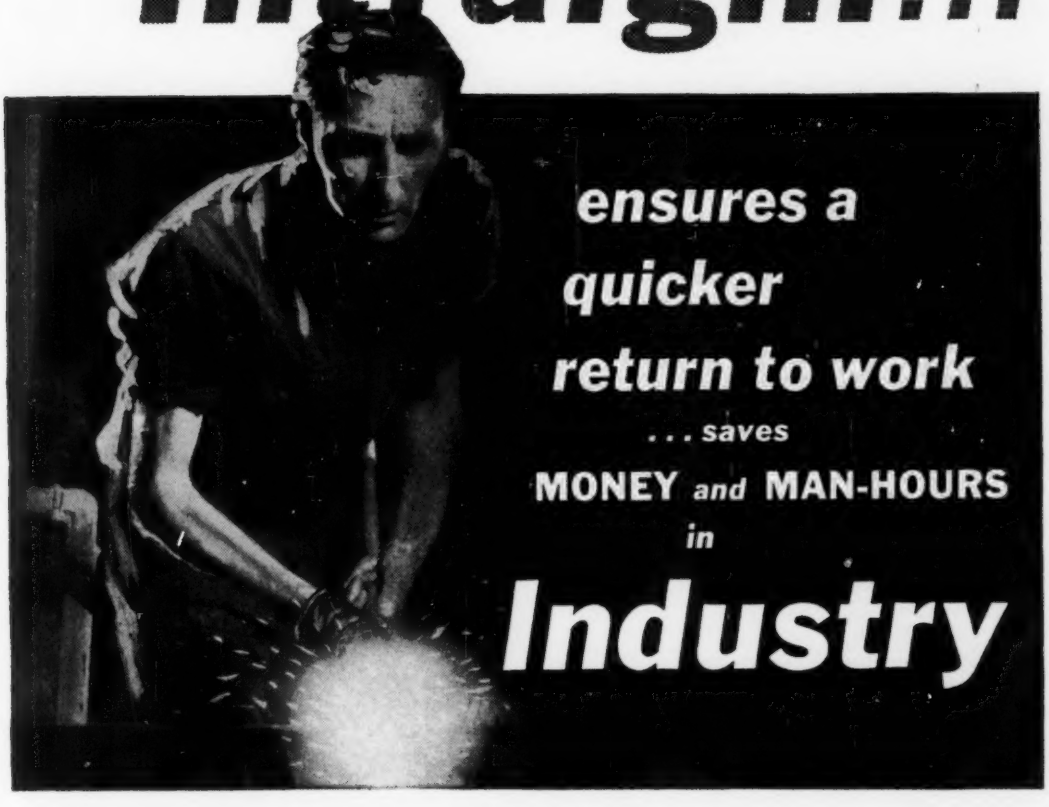

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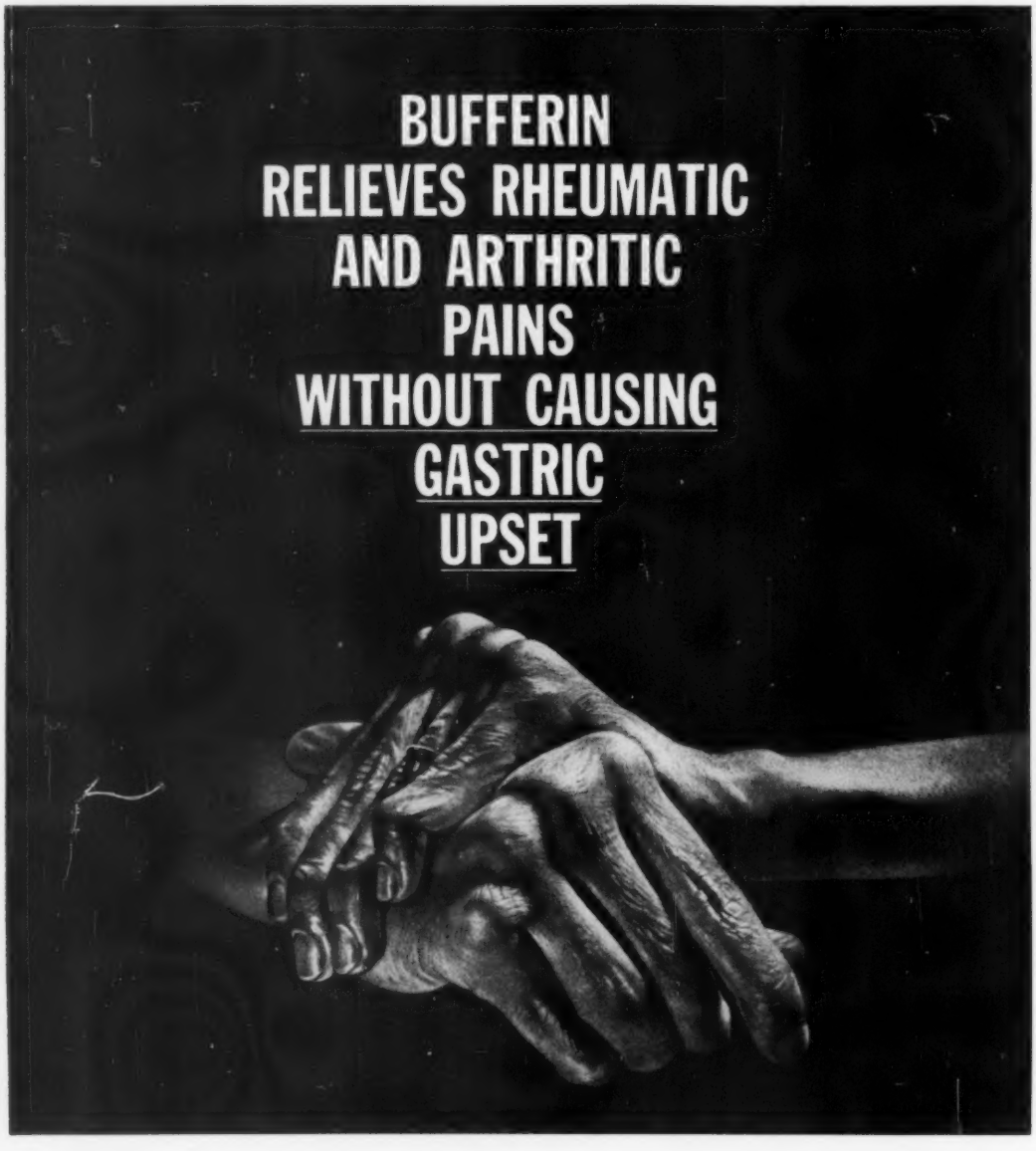

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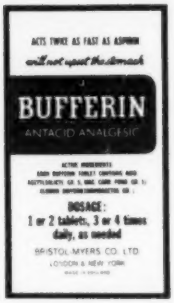
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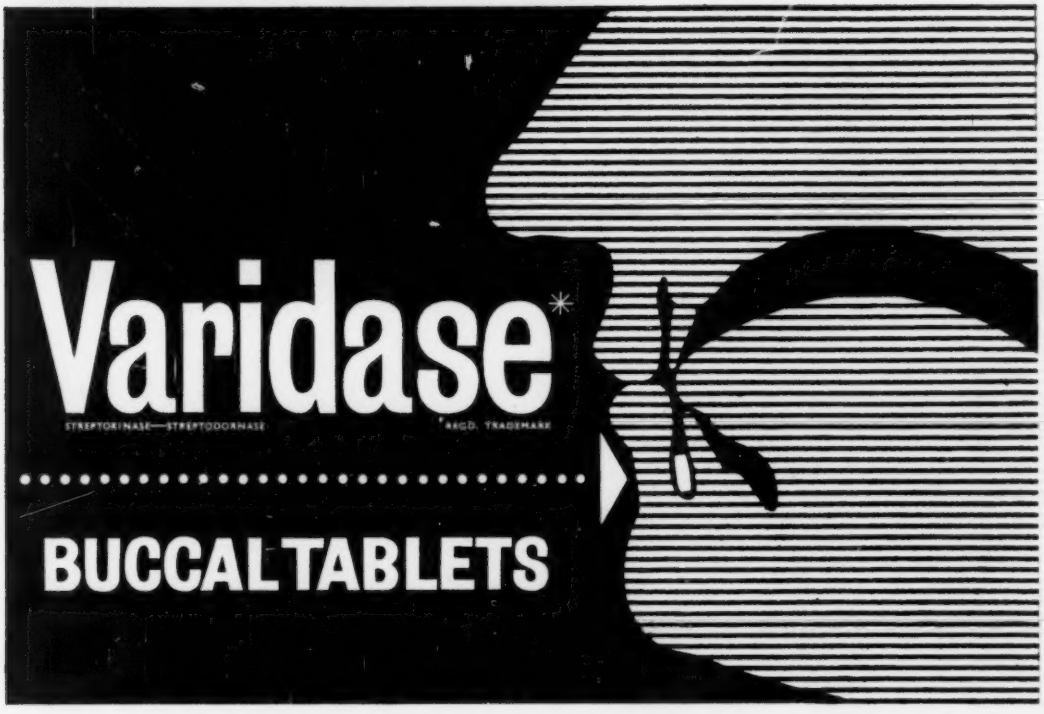

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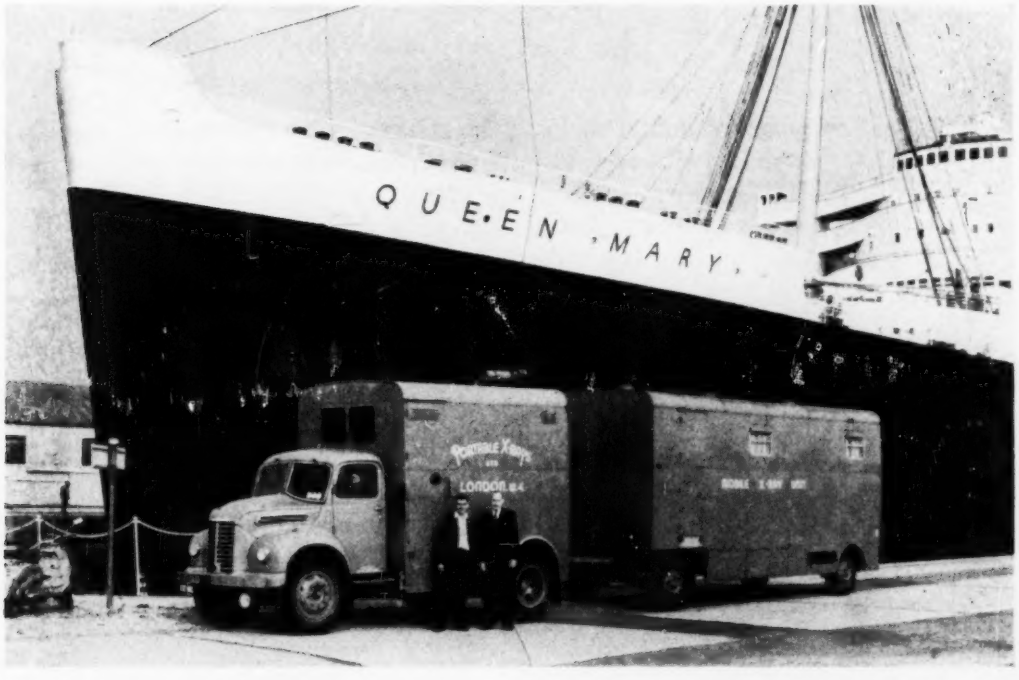

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BACKGROUND TO BYSSINOSIS IN ULSTER*

BY

JAMES A. SMILEY

From Queen's University, Belfast

(RECEIVED FOR PUBLICATION MAY 11, 1960)

The spinning and weaving of flax have been carried on as domestic arts all over Ireland for many centuries. In the late 18th century more efficient methods were introduced into the British Isles by refugee Huguenots. For historical, economic, and ecological reasons the manufacture of linen became concentrated in Ulster. There is no evidence of a respiratory hazard until mechanization of the processes took place.

Ramazzini (1705) described a severe respiratory affection amongst scutchers and hacklers aggregated for work in enclosed spaces. In 1831 Thackrah and Jesse Leach (1863) described similar cases occurring in Leeds and Heywood, and in 1860 Greenhow noted the enormous increase in the mortality from respiratory disease following the introduction of linen manufacture to the Pateley Bridge area of Yorkshire. He recognized also the Monday exacerbation. In 1856 Malcolm in Belfast suggested, in a statistical study, that the incidence of respiratory disease was directly related to the dustiness of the occupation and in a series of papers from 1873 onwards Purdon (C. D.) and a number of other Ulster doctors described the syndrome.

It is my view that, although the incidence of the disease has markedly decreased, cases still occur and that clinically these are indistinguishable from byssinosis in the cotton trade. Recent observations on byssinosis in Ulster, with some typical case histories, provide the evidence for this view.

The invitation to give the Scott-Heron Lecture has given me much pleasure because I regard it not only as a personal honour but also as a compliment to that growing group of doctors (of whom I am one) whose main concern is with the problems affecting the health of men and women in their working environment. The fragmentation of medicine into an increasing number of specialties is perhaps the inevitable consequence of the advances which have been made in technology in the 20th century. Francis Hugh Scott whose bequest led to the establishment of this lecture would probably have deplored it. He was a general practitioner, born in 1865 and bred in the county of Down. He practised for 50 years in Saintfield amongst people whom he knew and loved. Their traditions he cherished, the habits and the customs of the countryside were an open book to him, seed time and harvest meant as much to him as to them, and when the crises of life and death were at hand he was at their side as a friend. He was held not only in great affection by them but in great respect; he was a good doctor. His undergraduate career was distinguished for he won, not only the Malcolm Exhibition but, in the winter session of 1890-91, the medal of the Belfast Hospital for Sick Children for distinguished answering on the diseases of infancy and childhood. His mother Caroline Scott, a daughter of Major Francis Heron of Killyleagh, was the great formative influence in his life and her memory is perpetuated in these lectures.

The History of Byssinosis

When first invited to give this lecture I planned to introduce the subject with some remarks on the beauty, the durability, the antiquity, and indeed some of the religious significance which surrounds the fabric "linen". I had hoped to refer to the huge output, probably by slave labour, in ancient Egypt; to the trade in the material across the Mediterranean Sea, to the introduction of flax to Britain by the Romans, to the encouragement of its culture in Ireland by the Brehon laws. Then we might have looked at the first definite reference early in the 13th century to a trade in linen in this country when it was said to be flourishing apparently in association

* The Scott-Heron Lecture delivered at the Royal Victoria Hospital, Belfast, on March 3, 1960.

with the abbeys of Bangor, Newtownards, and Armagh. As a matter of interest we could have considered the contribution of Strafford in Tudor times, his own private and unsuccessful venture into the trade, his suppression of piracy which was probably his chief contribution to trade in general and which, a generation later, led to the flight of more than 50,000 refugees from the Continent to these islands from France. It seemed for a moment that in this World Refugee Year one might well have loitered to consider in retrospect what we in Ulster owe to the Huguenot refugees and how it came about that although these foreigners, the majority of whom were acquainted with the arts of spinning and weaving, settled all over these islands, it was mainly in Ulster that the linen trade took root and developed. I would have liked to have examined the historical and economic causes which had this result; the nature of the crop, the terrain, the climate, the system of land tenure, the plantation of Ulster by the dour Presbyterian Scots, and then to have made a reference to William, Prince of Orange, who in 1698 invited a personal friend Louis Crommelin, a member of a wealthy Picardy family in the linen trade (another refugee), to become overseer of the Royal Linen Manufacture in Ireland.

For centuries the spinning and weaving of linen was a domestic industry and remained so until quite late in the 19th century. Indeed weaving as a cottage industry lingered on in a few areas until the First World War.

On some other occasion one might dwell on the romantic history of linen during the late 18th and 19th centuries, on the story of the Linen Board and the squabbles which ended it, of the drapers who travelled together from town to town to buy brown linen, in company, because of the disturbed state of the country and because of the large sums of money they carried; of the social consequences, the balls and the parties in the provincial towns, the erection of Linen Halls, the bargaining which went on between the weavers who brought their webs to market just as they brought their eggs and butter, the growth of the bleach greens, and the inevitable concentration of capital in the hands of the drapers which made the later industrialization of the whole linen trade possible, the theft of linen from the greens, the anecdotes connected with such exploits of thieving, the smuggling of stolen linen to the Isle of Man and elsewhere, the measures taken to stamp out all "these iniquities" and the reluctance of juries to bring in a verdict of "guilty" because the sentence meant transportation for life. One could, perhaps, with profit, examine the industrial unrest which was with us even in those days and its manifestations in strikes or "turn outs" as the weavers called them, not infrequently resulting in riots. In 1762 for example the weavers in and around Lisburn rose in revolt, formed riotous mobs, destroyed property, and defied Parliament because they resented the introduction of a Bill concerning the inspection of brown linen. It is reported (Irish Linen Trade Hand Book and Directory, 1876), however, that they "quickly came to a state of repentance for the acts of folly and wickedness committed" and they presented an address to the Irish Linen Board: "May it please your Honours, we should have been amongst the first to express our sincerest gratitude and thankfulness for the happy regulations you have made in our trade, had not grief and shame for the late enormities committed in and about this place withheld us from presuming to lift up our faces before you and the public". Here is a vein of our social history which remains to be worked out. For a period of about 40 years from 1784 until about 1828, when Mulholland's Mill in York Street was burned down, the main industry in Belfast was not the manufacture of linen but of cotton. It is virtually certain that conditions in the trade in those days were such that it seems inevitable that cases of byssinosis must have been frequent. In spite of that fact, although Ireland, its politics, its trade, and its agriculture was at that time under the almost continuous scrutiny of Government Commissions and committees, and a long stream of observant visitors from both England and the Continent, who amongst other things did comment on the health of the people, no remark seems to have been made of respiratory disorders amongst textile workers. Later in the century W. M. Thackeray (1843), who seems to have had an eye for a pretty girl, visited a spinning mill on a visit to Belfast and commented on the plumpness and rosy complexions of the girls he saw there. It must be remembered, however, that the Industrial Revolution had scarcely touched Ireland by the time it was reaching its crescendo in Lancashire, for the low wages paid to hand spinners made mechanization hardly worth while.

The first mention of the disease now known as byssinosis in an official document appears to have been made by E. H. Greenhow (1860). In 1863 Jesse Leach, certifying factory surgeon at Heywood, Lancashire, described the symptoms of the malady. "Mixers", he stated, "suffered from sneezing and coughing with much slaty expectoration, which was shown by the microscope to contain very fine short cotton fibres; their arms and hands were often affected with urticaria-like rashes". Similar symptoms were described in scutchers. Strippers and grinders were stated mostly to suffer from spasmodic

cough, bloody expectoration, asthma, and oppression of the chest. But 30 years earlier in 1831 Charles Turner Thackrah, the father of Industrial Medicine in this country, who lived in Leeds, then the thriving centre of a considerable linen trade, had recognized the malady: "Dressers of flax and persons in the dusty rooms of the mills, are generally unhealthy: The early stage of the malady which attacks flax men varies from that of ordinary bronchitis. The cough and difficulty of breathing are not so temporary: one precedes the other sometimes by months, more frequently by years. The cough is harsh; its invasion is generally confined to the morning and evening—and more to the latter than the former. In the early stage there is no mucous, pituitous or puriform expectoration and little even for years of cough". Thackrah then gave minute clinical details of 14 cases and incidentally commented on the diminution of the number of cases of drunkenness, attributing this result to a reduction in the wages of flax men. He noticed too that the air was exhaled at an effort even at the age of 18 but said explicitly that "The younger operatives, who are generally of the age of 7 to 12 were not examined". He continued: "The process of hackling flax is generally the most injurious to health. A large proportion of men in this department are young. Very few can bear it for 30 years and not one instance could we find of any individual who had been forty years either in this or any of the dusty rooms. There are indeed comparatively few old persons in any departments of the flax mills. On inquiry last year at one of the largest establishments in this neighbourhood, we found that of 1,079 operatives, the majority were children, but a considerable portion adults, there were only nine persons who had attained the age of 50; and besides these, only 22 who have reached even 40".

One of the things which impressed me most in reading through the writings of our 19th century predecessors in medicine and indeed their ancestors, is their readiness to prescribe practical measures affecting not only their patients but the environment in which they lived and worked. There was no distinction between clinical medicine and social medicine. It was all *Medicine*. Thackrah was no exception and his plan for creating a current of air directed downwards to a channel in the floor anticipated, in principle, the best of modern ventilation practice. But even Thackrah was anticipated. Ramazzini (1705) wrote: ". . . those who hackel the flax and hemp to prepare it for being spun and wove, afford frequent instances of the unwholesomeness of their trade; for there flies out of this matter a foul mischievous powder, that entering the lungs by the mouth and throat, causes continual coughs and gradually makes way for an asthma. The *hemp-combers* and hacklers are wont to come in great companies from the adjacent borders of France to Lombardy about the beginning of winter: for the people of our country are not so well versed in that part of the manufacture. Now we always observe, that that sort of people are daubed over with hemp dust, pale faced, subject to coughs, asthma and bleary eyed. The winter being the season allotted for that work, they are obliged to work in close places, and considering that the hemp is very greasy and oily, upon that occasion they cannot but take it in at the mouth of these foul particles that pollute the spirits and stuff up the organs of respiration. Add to all this, that the hemp and flax being steeped in stagnating and putrid water and daubed over with clay to promote its readier maceration under water, the particles thus imbibed cannot but be virulent and open enemies to human nature. These work people complain that they suffer more in hackling flax than in hemp; and that perhaps, because of the powder or dust of the former is subtiler and so making a smarter irruption into the organs of respiration, provokes them more sensibly to throw off the clog that galls them".

Ramazzini concluded "But at the long run if they find their affliction grows upon them they must look out for another trade; for 'tis a sordid profit that's accompanied with the destruction of Health".

In the latter half of the 19th century in Ulster there appears to have been an awareness not only amongst a group of doctors but also in the linen trade itself and beyond, that there was a severe respiratory hazard in all the dusty processes concerned with the manufacture of linen. Hamilton (1873), Medical Officer of the Cookstown Workhouse Hospital, after stating that he had the supervision of some 30 scutch mills and commenting on the very high rates of both fatal and serious non-fatal accidents in them, recorded: "These scutch mills being often mere hovels, with low roofs and very bad ventilation, were it not for the usual six months cessation between each season's crop of flax, the injury to the workers constitution would be very trying indeed; but getting work in the spring in the open fields helps to restore them. Chronic bronchitis, often ending in phthisis or asthma, frequently ends the days of the scutcher, his place always supplied by stout agricultural boys who in a year or two, show signs of the unhealthy trade by heaving chest and short breathing".

In the same year Newett of Ligoneil (Newett, 1873) in an "Address to Millworkers" said "That employment in Flax Mills tends to bring about consumption and other diseases of the chest, does

not admit of doubt". So well was the risk recognized, he said, that the Army Surgeons forbade recruiting sergeants to enlist flax dressers to the Army.

In the absence of the diagnostic aids which are now available there may often have been a confusion between the various types of chronic pulmonary disease, tubercular and non-tubercular. A careful study of the investigations of two Belfast doctors disposes of any doubt, for the symptomatology and the epidemiology described by Purdon in numerous papers and by Malcolm (1856) are not those of tuberculosis. After describing in detail the various processes of hackling, preparing, carding, roving, spinning, and doffing, Malcolm remarked on the relative dustiness of the various departments and came to the conclusion that the smallest particles of dust were the most dangerous.

With the advantage of instrumentation for dust sampling and dust measurement Roach and Schilling (1960) confirmed this view. Their most recent work suggests that although the dangerous cotton particles are microscopic in size they are of the order of 7μ and larger, an important point in relation not only to the aetiology and pathogenesis but to the engineering problem of control.

Malcolm compared factory workers with non-factory workers drawn from the same social class and he emphasized the point. He showed in tabular form that amongst the preparers, the incidence of diseases of the chest amounted to 12·2%, in spinners 4·1%, in reelers, a relatively non-dusty process, 0·9%, and in weavers, another fairly clean occupation, 1%. He claimed that the more dusty the process, the greater the incidence of respiratory disorder.

In the returns from the six dispensary districts of Belfast from 1852 to 1855 there were 2,503 mill workers, 394 males and 2,109 females. The percentage with disease of the chest amongst these amounted to 18·7% compared with 6% amongst the total 35,039 attending the dispensaries during the same period. There were only 65 hacklers, 21 of whom had "pulmonary affections, though not of phthisis; pulmonary disease, generally bronchitis, is *par excellence* the hackler's malady" (Malcolm, 1856).

When this paper was read Charles Delacherois Purdon was 36 but it was not until another 20 years had elapsed that there began to issue from his pen a series of papers and reports describing the ravages wrought on workers by the inhalation of flax dust. The leaders of the industry were concerned by what they learned and helped Purdon in his inquiries, with the apparent result that the incidence of the disease was so reduced that, as Logan (1959) pointed out, the leading physicians in Belfast at the end of the century barely mentioned it in their works.

Purdon (1877) wrote: "The different processes that flax has to go through before it is made ready for clothing our person or adorning our houses causes certain diseases in those that are employed in its manufacture, but one of the most injurious and in certain branches very fatal is the effect induced by the inhaling of flax dust, called by the workers 'pouce' which is produced when the fibre is cleansed by machinery from the decayed wood and earth that adhered to it in the steeping pools. This is largely given off in the Scutch Mills where it is inhaled by the scutchers and those employed at the rollers through which the straw is passed . . . not so with flax dressers (roughers and sorters) who are constantly inhaling the dust . . . The injurious effect that this inhalation of pouce produces on the lungs begins to manifest itself oftentimes in a few months, but more frequently in a few years . . . the worker seizes any article that he may be near in order to enable him to get over the attacks more easily—in which case he is said to be 'poucy'."

Purdon (1875) stated "a class to which I would draw especial attention is the carders whose life averages 45·7 years and the average length of time employed as such is only 16·8 years. I may mention that if a girl gets a card at 18 years, her life is generally terminated at 30 years. The next class that suffers greatly from the effects of the Pouce is the Preparers and the average time that they work is 28·7 years and the longest time any have been employed in the department is 48 years. With regard to weavers, winders and reelers, I may say that when workers that are employed in the unhealthy departments begin to feel that they are suffering from affections brought on by their employment in the same, they at once select (if they can) the healthier processes, begin to learn them, but the chest disease has already made too much progress and their lives are only prolonged for a short time. The departments generally selected are the Weaving, Winding and Reeling."

This group of 19th century physicians recognized little more than a respiratory hazard which was similar to bronchitis if not actually bronchitis, though they also mentioned asthmatic episodes. They recognized too that the more dusty the process the greater the risk, and indeed Malcolm was precise in identifying the smallest dust particles as being the most dangerous. There is little evidence that any of them recognized what we now believe to be the most characteristic feature of the disease namely the Monday exacerbation. True, Purdon (1875) did say "The spinners suffer from oedema of the legs and ankles, also from varicose veins, and on each

Monday morning after being in for a short time many of them become so faint and giddy that they are obliged to go out into the lobbies in order to recover themselves", though why varicose veins and oedema of the ankles should cause more acute symptoms on a Monday morning is not quite clear.

Greenhow (1860) produced a monumental report for the Privy Council which was presented to both Houses of Parliament and to which in subsequent reports he added much fresh data. It was he who first described in detail the disease in the cotton trade which we now know as byssinosis. The name *Byssinosis* was first used by Oliver (1908). It is derived from the Greek word "bussos" meaning "fine linen"; there was no classical Greek word for "cotton". Greenhow, although he visited Ireland, examined only the mortality rates for respiratory diseases in different districts of England. He visited Pateley Bridge in Yorkshire and after noting the enormous increase in the mortality from respiratory disease since linen manufacture came to the area, Greenhow continued "The effects of exposure to the dust of flax are manifest on the mucous membranes. The stomach is very apt to become deranged by the dust swallowed, and hence flax operatives more particularly hacklers often suffer from dyspepsia and are sallow and look sickly; the eyes often become sore, the margins of the eyelids being swollen and inflamed and the sight is said occasionally to become impaired. But the most serious effect is produced on the mucous membrane of the air passages; oppression of the chest, followed by dyspnoea, cough and eventually expectoration are ordinary results of inhaling air charged with the dust of flax. It is remarkable that dyspnoea sometimes of an asthmatic character often long precedes the accession of cough and expectoration or perhaps more properly speaking the cough and expectoration are in the beginning too slight to attract the notice of the sufferer, whilst the dyspnoea reminds him of its presence whenever he attempts brisk locomotion. . . . Many of the flax operatives forsake the occupation at an early age on account of the injurious influence it exercises over the health but though this is true, the injury to health is commonly very gradual and constant discomfort and serious disease only become established towards middle life, men employed in any dusty department of the manufacture rarely attaining the age of 45-50 without suffering more or less severely from bronchial disease. So completely aware are the masters of the injurious nature of this occupation that some of them have endeavoured to introduce the use of respirators. . . . It was stated that operatives are more affected by the dust at the beginning than at the close of the week and that they always suffer more on resuming the employment after an interval of cessation. . . . As life advances, the power of resisting the pernicious influence of their occupation diminishes and more or less permanent dyspnoea and other results of bronchial irritation, supervene."

Greenhow was a detached man, as befitted a civil servant and an able observer, and his first report penned 100 years ago is still worth detailed scrutiny. His work on cotton has long been accepted but we are only now beginning to rediscover it and realize its significance. In particular he recognized in flax workers the exacerbation which in the cotton trade is called "Monday fever". (This Monday exacerbation must be distinguished from three other conditions to which the name "Monday fever" is given, *i.e.* the fever and headache of metal fume fever or brassworker's ague, the mill fever which occurs or used to occur in youngsters when they first entered the spinning rooms, usually on a Monday and which lasted a few days, and the Monday headache of which workers with the aliphatic carbon compounds, *e.g.* dynamite and cordite often complain.)

Another observer of the linen trade was Osborn (1894) who pointed out that "workers with 'mechanical phthisis' or 'flax dressers' phthisis' always improve on withdrawing from the work for a period but immediately deteriorate on their return".

He communicated with 16 doctors, nine in Ireland and seven in Scotland, with experience of the linen trade. All of these recognized the hazard though not all believed that dust was the cause; one attributed it to the hot humid conditions, although Malcolm (1856) found that in the humid rooms the incidence was low, and another attributed the disease to the social conditions in which the workers lived. In general, the report of Dr. Alex D'Evelyn of Ballymena (quoted by Osborn, 1894) could be considered typical. He wrote "Hackling is the most deadly process. . . . The hacklers all die young and all suffer from chronic diseases of the lungs caused by the flax dust or 'pouce' as it is locally named. Many of these men succumb to cirrhosis of the liver or to disease of the kidneys but this is partly due to the amount of raw alcohol which they consume. The first thing a hackler does each morning is to drink a glass of raw whiskey to clear out his bronchial tubes otherwise he is unable to breathe. After a day off, the men often told me that their breathing is worse". Arlidge in his Milroy Lectures of 1889 and his textbook "Diseases of Occupations" (1892) accepted the evidence and described in similar terms the respiratory hazard to which workers in the early stages of processing flax were then exposed. Sir Thomas Oliver (1902) in his book "Dangerous Trades" included a chapter by H. S. Purdon in which was discussed the high incidence

of what is called "asthmatic bronchitis" in the dustier parts of the trade and commented on the relative absence of the condition in the damp humid spinning rooms.

After the close of the 19th century interest in the condition appears to have waned and as Logan (1959) pointed out there are few, if any, references to it in the literature. Sir Thomas Legge (1934) in his book "Industrial Maladies" said "the same evidence of bronchitis symptoms simulating asthma was forthcoming, from the inhalation of flax dust in scutching mills, in hackling and preparing"; and in her reminiscenses, "From One Generation to Another, 1839-1944", Hilda Martindale (1944), who was a Factory Inspector in Ireland from 1905-1912, referred to the prevalence of asthmatic bronchitis in the mills. But it is not improbable that the evidence to which Legge referred was that which I have reviewed above and which was, by 1934, considerably out of date, and Hilda Martindale may have been observing the residuum of cases from a previous generation. Indeed, as I have already indicated, H. S. Purdon in 1902 appeared to be satisfied with the state of affairs then existing.

My interest in this subject dates from 1933 when I entered general practice in Belfast and soon became aware of the large number of women in the practice with chronic bronchitis and emphysema. At that time there was much unemployment in the mills and there appeared to be little that could be done to determine whether or not there was an association between the occupation and the malady, as was alleged. During the Second World War, however, it became increasingly clear that in a mill spinning hemp, to which I was adviser, card room operatives were exposed to a respiratory hazard (Smiley, 1951). At the same time it was obvious that similar cases were occurring in the early stages of processing flax for spinning. In 1947 I recognized the similarity of "pouce" as the Belfast workers continued to call it and "byssinosis" as it was being investigated by Schilling in Lancashire. Later Schilling and Hughes visited Belfast and to each independently were submitted a group of 14 cases of "pouce" in hemp workers, with a similar number of cases of other respiratory disorders, and 12 cases of "pouce" in flax workers and the same number of controls. Each picked out the cases, which they declared to be indistinguishable from byssinosis and the only conflict of opinion between them concerned the category of severity into which two cases might be classified. As a result of this visit Nelson (personal communication) has made an objective measurement of respiratory efficiency amongst card room workers handling hemp and measured the prevalence of symptoms of byssinosis among the rope workers. This work has not yet been published.

Recent Observations on Byssinosis in Ulster

There appears to be some reluctance in Northern Ireland to accept the fact that under modern conditions cases of byssinosis, due to the inhalation of flax dust, still occur. It certainly seems true that the incidence of the condition has greatly declined since the turn of the century, but we know very little about its epidemiology. It was thought in 1947 that the disease in Lancashire had been almost eliminated. In the six years between 1942 and 1947 only 39 cotton workers out of some 60,000 at risk, were deemed to be disabled by the disease. But the size of the problem had been grossly underrated, "for in 1956 and 1957 when the scheme was expanded to include partially as well as totally disabled men and women, 408 cotton workers were awarded pensions for byssinosis" (Schilling, 1959). A field study of cardiovascular-renal disease in cotton workers with special reference to hypertension had been undertaken by the Department of Occupational Health in Manchester. A completely unexpected finding in the course of this survey was that 66 of the 131 card and blow-room workers complained of tightness of the chest on Mondays; moreover, 15 of those affected were permanently and severely disabled. As a result, a detailed and precise survey was begun in order to ascertain the prevalence of byssinosis. This survey confirmed the chance finding in the earlier one and revealed that 14% of the middle-aged men were in some degree disabled. (In the cotton trade men work at the dusty processes.) The nearer the operatives were to the carding engines, the higher was the prevalence of byssinosis amongst them (Schilling, 1956).

It has been known for a very long time (as I have shown above) that workers in the dusty rooms of flax spinning mills are exposed to a respiratory hazard and, recently, cases have been seen and described, which are clinically indistinguishable from cotton byssinosis. A survey is now needed to determine the prevalence of the condition. My impression is that the incidence of byssinosis in the linen trade is less than in the cotton, for two reasons: first, because of the suppression of dust by wet methods of spinning, and second, because many of the workers in the dusty processes are women. Women tend to be absent from work during their child-bearing period and as they are often not entirely dependent on their own earnings when they do return, they can leave the trade or change their occupation if their health deteriorates. It is probable that, compared with Victorian times, the shorter

working day, the improvement in working conditions, and the smaller number of workers employed in the spinning of flax fibres (as distinct from the man-made fibres) have all contributed to the fall in the number of cases of "poucey chests" seen nowadays. Many questions remain to be answered. What components have flax and cotton dust in common? What is the dangerous element? Is it found in flax dust of every particle size? Must all dust be suppressed or extracted or can the engineers concentrate their efforts on the removal only of dust of a certain range of size? Can the offending agent be neutralized by chemical or other means? Or can the workers exposed to risk be rendered immune? Is the action of dust on the lungs non-specific or a function only of particle size? Is the action perhaps due to contaminants, *i.e.* bacteriological or fungal?

Is byssinosis as rare in cotton mills in Holland and the United States as is often said? If so, why? In America it may be that workers do not remain long enough at the trade to develop the condition but that is not the case in Holland. Are our criteria of diagnosis different or are other factors concerned, such as climate or social environment?

Pharmacological studies are proceeding in this country and in Holland. The results are not yet available, but Bouhuys, Lindell, and Lundin (1960) found evidence that the offending fraction in cotton dust is not histamine as was once thought, but a substance which is capable of releasing histamine. They have also shown experimentally that inhalation of an extract of cotton dust can cause a delay in the clearance of nitrogen from the lungs during oxygen breathing.

The effect on medical students of inhaling cotton dust has produced interesting and occasionally alarming results which are being studied and two other investigations which may prove to be relevant are designed. The first should show the effect of breathing for a prolonged period an atmosphere laden with an inert dust such as calcium carbonate. The second is a comparison of the ventilatory capacity of coal-miners exposed to heavy concentrations of coal dust, who suffer no fall in ventilatory capacity during the course of a working shift, and mill workers exposed to cotton dust who do (McKerrow, McDermott, Gilson, and Schilling, 1958).

Clinical Observations and Typical Case Histories

Both men and women are affected and in those affected the condition is usually well established by the time complaint is made between the ages of 45 and 55. Cases occur outside these age limits. Commonly at the onset the worker complains of "tightness of the chest" on resuming work after the summer holidays.

Case 1.—A hackler aged 37 played in a flute band as his hobby. On the day he returned to work after the holidays he felt "stuffed up" but attributed this in his own phrase to "the unusage". He felt tired at the end of the day and did not go to band practice on Monday evening. He was "chivied" by the bandmaster for his non-attendance and promised to attend on the following Monday. During the week he noticed nothing unusual. Shortly after returning to work the following Monday morning he again noticed the tightness of his chest and felt tired all day. After his evening meal he felt better and went to his band practice, but left early because the effort was too much for him. On Tuesday and the succeeding days of the week he worked as usual but thereafter on Mondays the "pouce got him" as he explained. He could play the flute on Saturdays but the effort was too much for him on Monday evenings. The following year he had to give up playing for he was not allowed to play on Saturdays if he did not attend the practices on Mondays.

Case 2.—A man aged 55 came to the Medical Department to have his finger dressed. As sister dealt with him he banged his chest and said "my oul chest". Inquiry elicited the story that for about seven years he had been short of breath usually on a Monday morning. At first he was better after lunch but later he was "bad all day Monday". Once or twice he stayed at home on Monday but when he returned on Tuesday the condition was, if anything, worse. Of late he had begun to wheeze and although he was free from symptoms at the week-end, he was affected on other days of the week as well as Mondays.

Case 3.—During the course of a pre-employment examination in an engineering works a man applying for a labouring job said that he had been employed for nearly 20 years in the preparing rooms of the flax spinning mills. When asked whether he was subject to colds, bronchitis, or other respiratory conditions he had said "No". In discussing his interests and hobbies, however, he said that he had given up attending his Lodge some years previously, because the meetings were held on Monday nights and he felt so tired on Mondays that he fell asleep by the fire in the evenings. It was only after a few loaded questions that he said that his "chest was always bad" on Mondays. He wanted a job away from the dust because his father had died of a "poucy chest" and he knew he was developing the same condition. He was subsequently employed in the engineering works and has had no further respiratory disability.

Case 4.—A middle-aged man who was employed in a country mill cycled to and from work. His first complaint had been some seven years previously, when on the day he returned to work after the summer holidays he felt great difficulty in breathing and continuing to work. He "soldiered on" feeling "not so bad". Later he noticed that on Mondays he was unable to cycle uphill to his home and he soon got into the habit of

getting his young son to meet him at "quitting time" each Monday, to wheel his bicycle home for him. As time went on the son was required to attend more and more evenings. After his summer holidays the patient had such extreme dyspnoea when he resumed work that he had to give it up. When I saw him some months later he remained seriously disabled. At rest he was symptom-free. He enjoyed fishing but any exertion caused him to wheeze and to cough. He said that he had greatly improved since he had left work. The only set-back he had had was on one morning when he was feeling better and he had visited the mill. When he returned home his chest felt tight and he had what he described as "the oul trouble back".

The women who are affected all give a similar history. Normally they leave their work and go home for lunch. Home is often only a few hundred yards away and they hurry there and back. Some notice that on Mondays they cannot hurry, and on that day they bring a "piece to work". On being asked why they cannot hurry the reply is often to the effect that their chest had been "stuffed up", that they felt their "chest tight", and occasionally wheezed. One woman said that at lunch time and at quitting time on Mondays she took a bus home but on the other days of the week she went on foot. Another said that, although she had been a heavy smoker, since she had returned to work after a lapse of 17 years she had never smoked on Mondays. "It was terrible" she said "I wanted to smoke but I knew I daren't because of my chest". Others are less specific about their earliest symptoms and a not unusual course of events is that for a period of months or years these middle-aged workers feel tired at their work on Mondays, and do not feel inclined to leave their hearth on Monday nights but accept this as part of the ageing process. The pattern of their Mondays imperceptibly changes until eventually they realize that the early part of the week at work is more exhausting than the latter part, that effort brings on wheezing and cough, and that the week-ends and holidays bring relief. The length of exposure to flax dust before this state is reached may be as little as five years but is more usually around 20 years. My impression is that a good many workers reach this stage but that relatively few progress beyond it. They are not seriously disabled so far as their work is concerned; they suffer from discomfort rather than disability. Schilling (1950) stated that in the cotton trade at this stage, bronchitis was not invariably present. My experience confirms that bronchitis is not *constantly* present. There seems, especially in those who progress to a further stage in the disease, a greater tendency to recurring attacks of acute bronchitis which leave no clinical signs except a few scattered rhonchi. Even at this stage a transfer or change of occupation ensures relief. In later work Schilling (1956) showed that a clear distinction could be made between bronchitis and byssinosis on the history alone, particularly in the early stages of the disease.

An important point in the differential diagnosis from asthma should be mentioned here. The asthmatic usually develops his attack immediately he comes in contact with the allergen. The byssinotic worker usually does not experience his exacerbation until he has been at work for several hours. It looks almost as if the "build up" must reach a critical level before the trigger mechanism causing bronchospasm operates. Preliminary work (McKerrow *et al.*, 1958) has shown that the symptoms cannot be reversed by the use of anti-histaminic drugs. Also, the patient's difficulty in byssinosis is sometimes as much with inspiration as in expiration. This observation requires further elucidation.

If exposure to the hazard continues (and here I speak from experience with hemp as well as flax, for I believe the syndrome of each to be identical), the patients finds that his colds are hard to "shake off" or that they settle on his chest and are slow to clear. Attacks of acute bronchitis may recur with increasing frequency, with the production of mucus, mucopurulent, and then purulent sputum, but between the attacks there persists the cough which is sometimes unproductive but often productive of mucus. The sense of constriction of the chest may not be severe and is taken for granted not only at the beginning of, but all through, the week.

If the disease develops further, cough increases with the production of tenacious sputum which is difficult to expel; a paroxysm of coughing often ends with vomiting. Dyspnoea becomes more and more marked. The chest becomes barrel-shaped and fixed in elevation by the accessory muscles of respiration and the full picture of chronic bronchitis and emphysema develops. It is generally believed that such patients are invariably emaciated but that is not my experience. Cases which reach this stage nowadays are much less common than in my early days in practice. There are no characteristic radiological signs at any stage of the disease and it is probable that even today many of these cases are diagnosed as chronic bronchitis with emphysema, as indeed at this stage they are. But the aetiology may be missed. The report of the Departmental Committee on Compensation for Card Room Workers (Home Office, 1939) stated "clinical and industrial histories taken in conjunction with the condition found on physical examination are sufficiently characteristic to enable a properly constituted Medical Board to arrive at a definite conclusion that the disease is industrial in origin". I believe that opinion is still valid and true of the linen industry as of the cotton trade.

Prevention of Byssinosis

Without delay, every available method should be used to *suppress* dust by whatever means are compatible with proper processing, and if these are

inefficient, to extract the dust from the atmosphere as close to its site of origin as possible. In the cotton trade it has been shown that the Shirley pressure point system substantially reduces the dust concentration in cardrooms with beneficial effects on the operatives (McKerrow *et al.*, 1958; Ministry of Labour and National Service, 1957). The adoption of this or a similar system seems to offer at least some hope of a solution of this problem. This, however, is a matter for decision by engineers. As doctors we are concerned with people and with the effects of environment on them. In this connexion there is a final word to be said. Workpeople will not and should not be expected to wear masks, except for short periods and in the presence of imminent risks. The fundamental solution of the dust problem is outside the control of the worker.

The preparation of this lecture has been a pleasant task and I wish to acknowledge the help of those who have made it so. I am especially grateful to my secre'ary Mrs. S. Stevenson who without complaint typed a number of drafts and helped me to revise and reduce to manageable size a large mass of material, to Miss Webster of the University Library, to Mr. J. W. Vitty of the Linenhall Library, to Mr. A. H. George of the Belfast Art Gallery for slides, to Mr. G. A. E. Roberts, O.B.E., Flax Spinners Association, for the loan of coloured transparencies, and to Mr. Victor Bell for projecting them. Most of all I am indebted to my wife without whose interest and encouragement the work would not have been possible.

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PULMONARY FIBROSIS IN WORKERS EXPOSED TO FINELY POWDERED ALUMINIUM

BY

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Of 30 workmen at risk 27 were examined and six found to have evidence of pulmonary fibrosis. In the two fatal cases the evidence for pulmonary fibrosis was conclusive and in three other cases it was sufficient; in one case it was suggestive. The clinical, radiological, and pathological features of these six cases are recorded. Results of respiratory function tests on the four non-fatal cases are given. The manufacturing process is described. An analysis of the powder is given, also the results of dust measurement in the contaminated atmosphere. The literature is reviewed and our own experience compared with reports from Germany and Canada. We concluded that the pulmonary fibrosis was caused by the dust inhaled at work and that the component responsible was finely divided aluminium.

Pulmonary fibrosis in an aluminium worker in Great Britain was first reported by Mitchell (1959). A footnote to that paper said that the man who replaced this workman had died of the same disease and that two ambulant cases had been found. The factory made a very fine aluminium powder for fireworks known as "pyro" and a coarser powder for aluminium paint. We have examined 27 of the 30 workers known to have been at risk and now know of six cases. In the two fatal cases the evidence for pulmonary fibrosis was conclusive and in three other cases it was sufficient. In the sixth case there were minimal radiological changes and in view of the occupational history we presumed that we were dealing with a limited form of the same disease. Reviewing our material it seemed highly probable that the dust inhaled caused the pulmonary fibrosis. The increasing use of aluminium and its products in industry and its use as a prophylactic against silicosis called for a more detailed account of this experience.

Case Reports

Case 1.—A.G. died at the age of 22. After leaving school he worked as an agricultural labourer until he was 19 when he joined the factory in March, 1951 and worked in an atmosphere heavily contaminated with the "pyro" powder until disabled by breathlessness in December, 1953. This breathlessness, which was first noted in September, 1953 was the dominant symptom and progressed relentlessly until death eight months after he stopped work. By March, 1954 he had to walk slowly on the flat, though he was able to sleep comfortably with one pillow. Three months later the breathlessness was such that he spent most of the day in his bedroom; bouts of morning cough, producing occasional scanty mucoid sputum, were very distressing. On the night of August 29 his condition worsened and the following morning he was admitted to hospital desperately ill, pale, sweating, and cyanosed, in a stuporose state, feebly gasping for breath. His temperature was 100·4°F.; pulse 110 per minute; respirations 45 per minute; blood pressure was 95/70 mm. Hg. He died four hours later. Five months before he died he was admitted to hospital for investigation and was found to be a slightly built, young man of healthy appearance. There was no history of previous illness except in November, 1951, when he spent 10 days in hospital with second degree burns of the skin after an explosion at work. Respiratory excursion was poor and medium crepitations were heard mainly over the pectoral and sub-pectoral regions. A pulmonary diastolic impulse was palpable and a systolic thrust was felt over the lower end of the sternum. The chest radiograph (April, 1954) showed appearances of pulmonary fibrosis (Fig. 1). For the nine months he was observed the serial films showed no significant change. The barium swallow was normal, except that the oesophagus was a little displaced to the right in the superior mediastinum. A miniature film (Fig. 2) taken on June 16, 1952 a year after he started the job was correctly passed as normal.

At necropsy the body was wasted; all the organs appeared normal with the exception of the heart and lungs. Both lungs were lightly adherent to the chest wall and there were a few small areas of fibrinous exudate particularly between the lobes. Both lungs were shrunken apparently due to generalized fibrosis, this fibrosis being

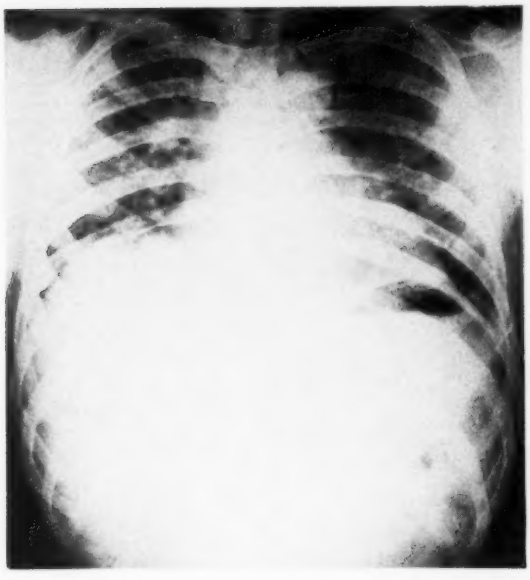

FIG. 1.

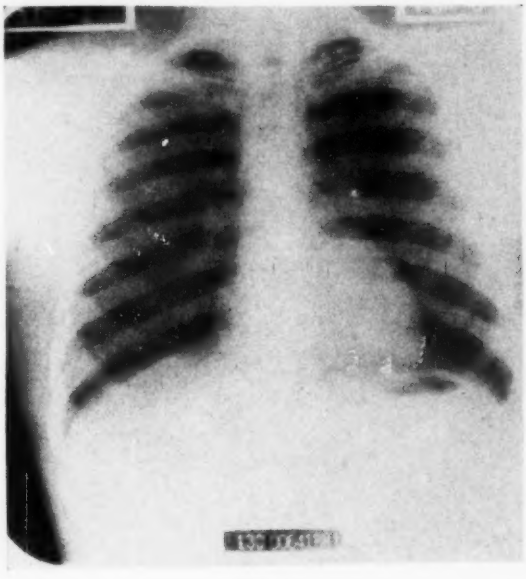

FIG. 2.

FIG. 1.—Case 1, chest radiograph in full inspiration taken on April 9 1954. Raised diaphragm (on screening respiratory excursion was greatly reduced); mediastinum drawn out; abnormal opacities mainly in the upper and mid zones; trachea kinked to the right.

FIG. 2.—Case 1, normal mass miniature radiography film of June 18, 1952.

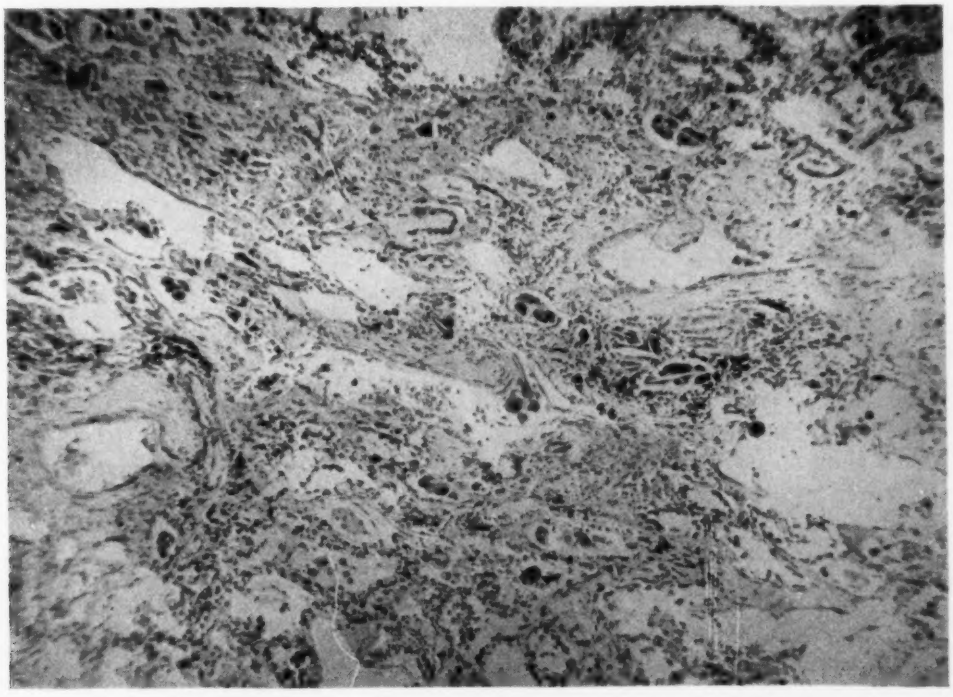

FIG. 3.—Case 1, low power (Haematoxylin and Eosin) showing pulmonary fibrosis, macrophages, and crystal clefts.

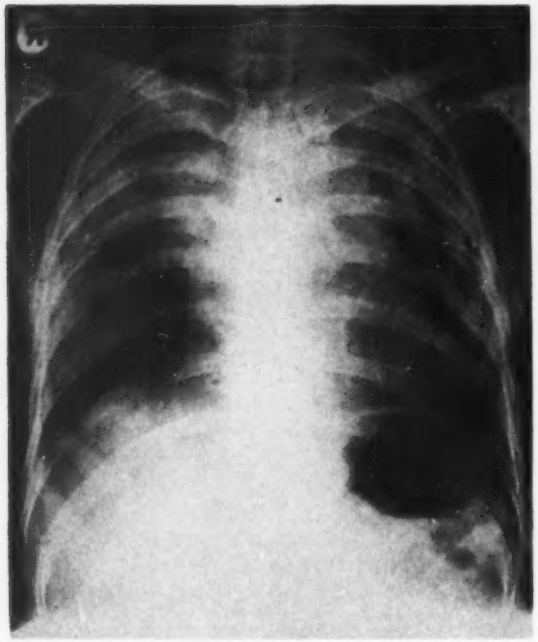

FIG. 4.—Case 2, film taken December 12, 1958, showing gross opacities mainly in the upper and middle zones. The whole mediastinum is pulled up and the trachea kinked to the right. On screening the excursion of the diaphragm was seen to be reduced to less than one inch.

FIG. 5.—Case 2, tomogram of January 28, 1959, showing the gross displacement of the trachea to the right.

FIG. 6.—Case 2, the barium swallow shows that the oesophagus is also sharply displaced to the right.

most marked in the upper lobes. The heart weighed 16 oz. and the right ventricle was dilated and hypertrophied. Microscopical examination of the lungs showed a generalized diffuse fibrosis, non-nodular in character and much of it acellular (Fig. 3). The fibrosis showed varying grades of severity in different areas. Areas of dense fibrosis were present up to 0·5 cm. in diameter and from many of these centres strands of fibrous tissue radiated. The pleura and the connective tissue in the septa were thickened. The moderate number of macrophages present contained pigment and a few very small particles which stained for lipoid but there was no lipoid pneumonia. There were a few giant cells with crystal clefts. Specific staining for aluminium with aurine showed numerous pink particles, apparently aluminium. There was no inflammatory infiltration. There was an occasional area of mild emphysema. There was no obvious endarteritis. Chemical analysis for aluminium showed 227 p.p.m. in the wet lung at the root, 15 p.p.m. at the apex, and a trace at the base. There was no evidence of sarcoidosis, tuberculosis, or other specific disease. Except for the absence of gross emphysema the appearances were similar to those described by Shaver and Riddell (1947) and Goralewski (1950).

Case 2.—E.B. died on February 10, 1959 at the age of 53. Apart from four years war service with the Royal Air Force he had spent all his working life out of doors mainly as a driver in the fish trade, until he joined the factory in May, 1954. He occupied the very job vacated by Case 1 until December, 1957 when breathlessness, which had begun seven months earlier, compelled him to stop. During the previous 18 months he had lost nearly two stones in weight. There were no other symptoms.

When examined on December 19, 1957, he looked pale, thin, and ill. His chest expansion was poor. Medium crepitations were heard over the pectoral and subpectoral regions. Blood pressure was 120/80 mm. Hg, pulse 80 per minute, regular. The chest radiographs were grossly abnormal (Figs. 4, 5, and 6). He said that a chest radiograph taken in 1942, before war service, was normal. By October, 1958, he was very slow on the flat and had to rest several times on the stairs. He had a hoarse voice and immobile left vocal cord (no cause other than pulmonary fibrosis and kinking of the trachea was ever found for this). He had lost nearly a stone in weight since his previous attendance. Pulse 110 per minute, regular. A diastolic impulse over the pulmonary area was palpable. Blood pressure was 100/70 mm. Hg. On December 12, he reported that his breathlessness was worse. On the morning of February 10, 1959 his general condition began to deteriorate and he was admitted to hospital in a weak state, pale, sweating, cyanosed, and breathing rapidly and feebly. He died about 12 hours later.

At necropsy all the organs appeared normal except the lungs which were densely adherent to the chest wall and the diaphragm, the adhesions being particularly strong at the apices. The lungs (weight 76 oz.) showed well-developed rib markings, marked pleural thickening, and well-developed bronchopneumonia in both lower lobes. There was bullous emphysema of the left upper lobe and right lower lobe and generalized emphysema of the left upper lobe and the whole of the right lung. Carbon pigment was particularly heavy in both upper lobes. The heart (weight 12 oz.) appeared normal in size. There was minimal atheroma in the arteries and a mural clot was attached to the wall of both ventricles. Microscopical examination of the lungs showed a diffuse fibrosis similar in type to Case 1 but apparently not quite so severe and with fewer acellular areas (Fig. 7). There was no evidence of tuberculosis or sarcoidosis in the lungs and no endarteritis. The appearances in this case were similar to those described by Shaver and Riddell (1947) and Goralewski (1950). Specific staining for aluminium with aurine showed only scanty particles of aluminium. Numerous macrophages were present, a few of which contained minute granules which stained for lipoid and others crystal clefts. Chemical analysis for aluminium showed 12·0 p.p.m. in the wet lung at the root, 15·75 p.p.m. at the apex, and 8·5 p.p.m. at the base.

Case 3.—A.R., born on July 5, 1914, left school at 15 and worked in a cotton mill until he was 22. For the next five years he worked in the moulding shop of a locomotive works until he was called up for military service from 1941 to 1946. After the war he worked as a labourer not unduly exposed to any dust, except for the one year March, 1953 to March, 1954 when he worked

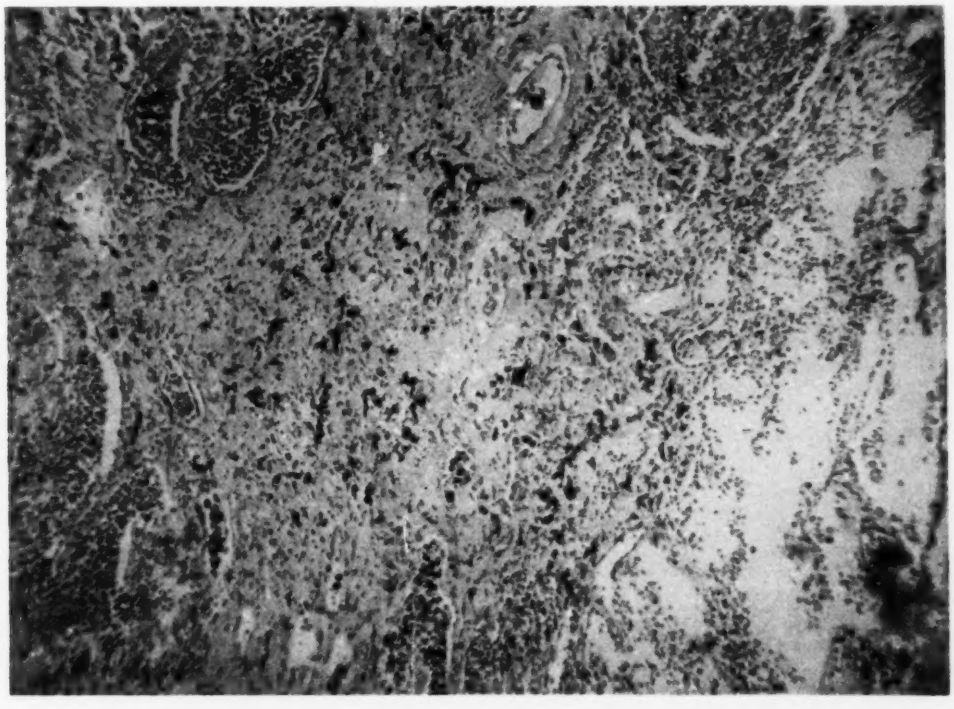

FIG. 7.—Case 2, low power (Haematoxylin and Eosin) showing pulmonary fibrosis, bronchopneumonia, and pigment.

FIG. 8.—Case 3, film of December 23, 1958. Abnormal opacities mainly in the upper zones, the mediastinum drawn upwards and outwards.

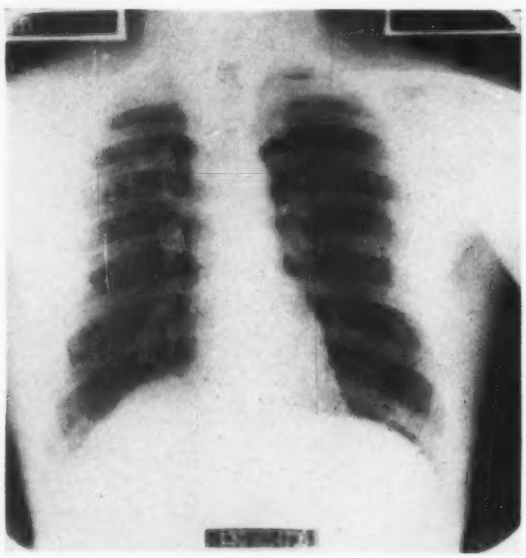

FIG. 9.—Case 3, normal mass miniature radiography film taken on March 5, 1952.

in the factory "polishing" the aluminium powder and then packing it. He had little or no contact with the "pyro" powder. He was under investigation as a suspected case of pulmonary tuberculosis when first seen by one of us (J.M.) on December 23, 1958. The radiographic appearances (Fig. 8) were thought to be very suggestive of aluminium fibrosis and it was then learned that he had spent a year at the same factory having left four years previously. He had no symptoms and looked well. Rhonchi were heard over both pectoral regions, more so on the right side, and the trachea was deviated to the right. The pulmonary second sound was increased. A miniature film (Fig. 9), taken a year before he started work with aluminium powder was normal.

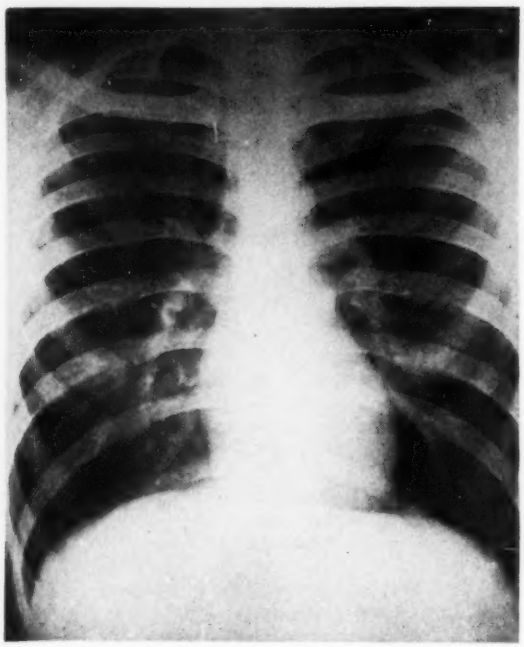

FIG. 10.—Case 4, normal film taken February 11, 1954.

Case 4.—A.B., born February 3, 1921 was first examined by one of us (J.M.) on February 2, 1959 as a result of the search for ex-workers who had been exposed to the "pyro" dust. He complained of a cough, especially troublesome on change of atmosphere, with scanty mucoid sputum, a choked-up feeling in the chest, and occasional wheezing. He thought he was a little more breathless than he should be on exertion but this latter symptom was only occasionally present and his symptoms were judged to be due to bronchitis. He left school at the age of 14 and was employed in a number of unskilled occupations. From 1950 he worked for four years with aluminium powder, two and a half years of which he worked with the "pyro" powder. Apart from three months working underground in a coal-mine there was no other history of exposure to dangerous dust. A chest radiograph was taken a month before he left the factory. This first film (Fig. 10) dated February, 1954 was normal. Another film (Fig. 11) taken about two

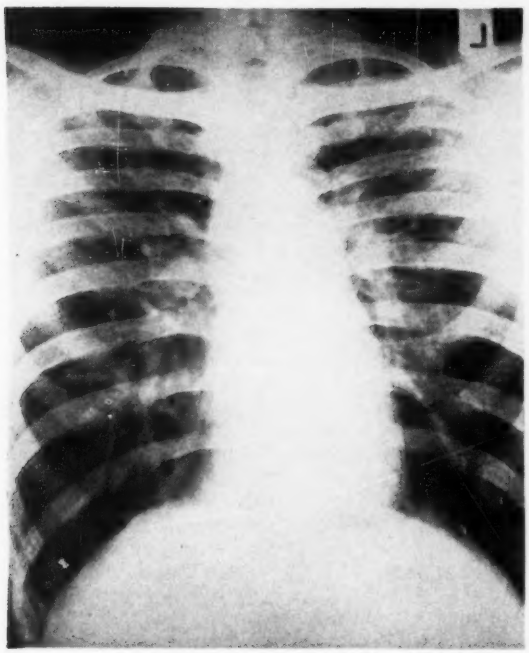

FIG. 11.—Case 4, film taken May 3, 1956 showing abnormal opacities mainly in the upper and middle zones, mediastinum pulled upwards and outwards, tension on the diaphragm indicated by peaking on the left side.

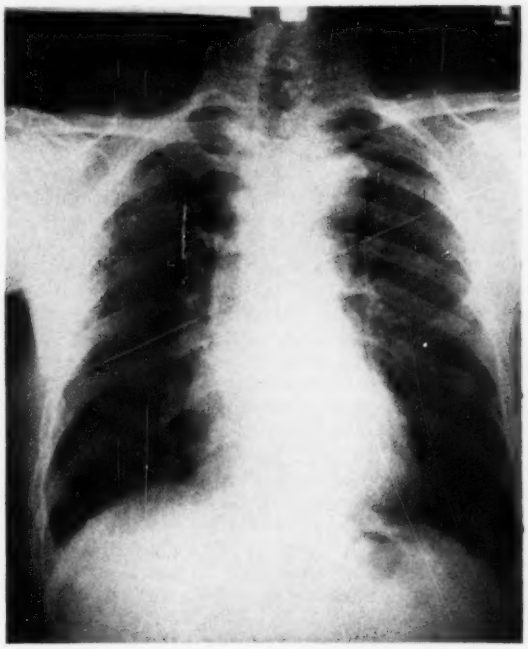

FIG. 13.—Case 5, film taken March 31, 1959. Abnormal opacities have appeared in the upper zones and there is a suggestion that the mediastinum has been pulled upwards and outwards.

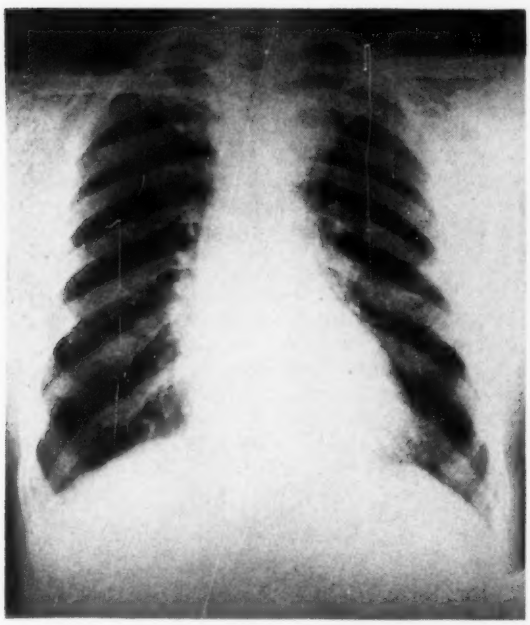

FIG. 12.—Case 5, normal film taken May 15, 1954 showing the rather high aortic arch which was thought to be due to unfolding of the aorta in an elderly subject.

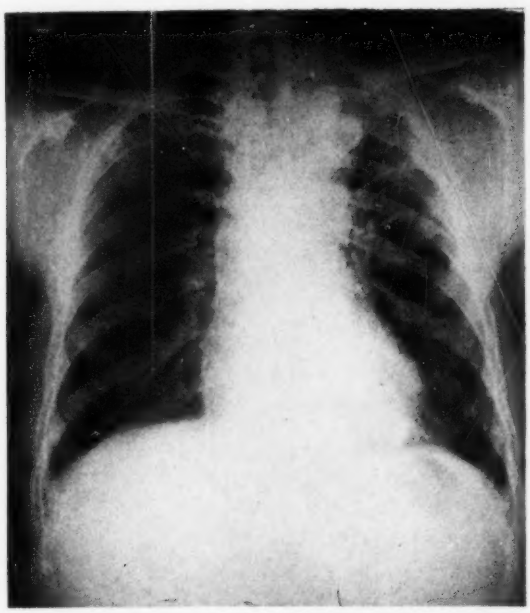

FIG. 14.—Case 5, film taken September 14, 1959. Following an attack of left upper lobe pneumonia the opacities on the left side became more marked. The greater part of the shadow due to pneumonia has resolved but a certain increased density has persisted.

years later was abnormal. He was a man of spare build who was troubled with eczema. Apart from reddening of the visible turbinals and posterior pharyngeal wall there were no abnormal physical signs. At the time he came to our notice, he had been attending a Chest Clinic for three years as a case of suspected tuberculosis.

Case 5.—N.J.L. was born on July 20, 1895. After Case 1 was diagnosed this man attended as a fellow worker in May, 1954, for medical examination and chest radiograph (Fig. 12) and nothing abnormal was found. He was re-examined on March 11, 1959, when the clinical examination was again negative but the radiograph (Fig. 13) was abnormal. On April 4, he was admitted to hospital with lobar pneumonia of the left upper lobe. This was treated conventionally and there was nothing remarkable about the course of the illness, except that the increased abnormal opacity on the left side never reverted completely to its former size (Fig. 14). A period of radiological surveillance which, at the time of writing, has lasted for 12 months, has failed to show any further change, and it was concluded that this partial failure of resolution was comparable with that which is sometimes seen in other forms of pneumoconiosis. Since this attack of pneumonia he has complained of increasing breathlessness on exertion and tiredness after work. For nine years he worked polishing and screening the coarser powder and spent only three months handling "pyro" powder. He was last seen in May, 1960 when he was still breathless but was able to do light work away from the powder.

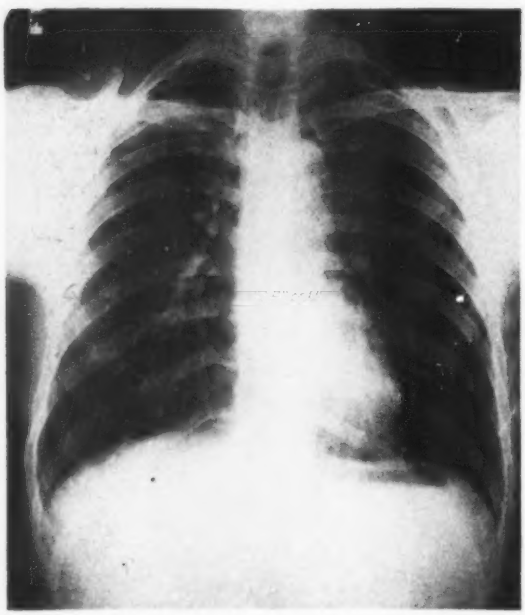

FIG. 15.—Case 6, film taken July 20, 1959. The abnormal opacities are slight and are best seen in the right first space. Subsequent films have failed to show any change.

Case 6.—J.C. was born on June 17, 1908. In June, 1959 a further list of names and addresses was obtained from the management and this man was among those who attended. He was examined and a chest radiograph was taken (Fig. 15) on July 20, 1959, when there were no symptoms nor significant abnormal physical signs. He had worked in the factory polishing and packing for three years from 1952 to 1955, always in the same room, and always with aluminium powder. He left school in 1925 and worked at a number of skilled and semi-skilled jobs but apart from his work with aluminium there was no employment in dusty occupations.

Tests

It was notable that no case showed clubbing of the fingers. The conventional laboratory tests were carried out on the first five cases. They all had negative Wassermann and Kahn reactions and the plasma albumin and total globulin were normal. In Cases 3, 4, 5, and 6 the serum protein electrophoretic pattern was normal, and the total and differential white cell counts were normal. Mantoux tests were negative in Cases 1 and 2 and positive (1/100) in Cases 3 and 5; they were not carried out in Cases 4 and 6. The erythrocyte sedimentation rate was normal in all except Case 5 where it was slightly raised. Skin contact tests were done using the "pyro" powder in Cases 1 to 5 and a 1% solution of aluminium nitrate and 1% aluminium sulphate on Cases 3 to 6 with negative results. In all cases the sputum was repeatedly examined for acid-fast bacilli with negative results; Case 2 had three fasting gastric juices cultured for tubercle bacilli, with negative results.

Respiratory function tests were carried out on Cases 3, 4, 5, and 6 by Dr. Colin Ogilvie, to whom we are grateful for Tables 1 and 2 and the interpretation of the results. The lung volume, ventilatory function of the lung, and diffusing capacity were measured.

In one patient (Case 6), the tests were entirely normal, in two (Cases 3 and 4) there was a moderate impairment of function, and in a fourth (Case 5) the defect was more severe. In all patients, the residual volume, ratio of residual volume to total lung capacity, and the forced expiratory volume as percentage of vital capacity showed relatively little abnormality. Furthermore, the reduction in maximum inspiratory flow rate was at least as great as the reduction in the maximum expiratory rate. These findings suggest that there was no important degree of airway obstruction nor emphysema. The reduced lung volumes indicate pulmonary fibrosis but the fact that the diffusing capacity was only reduced in proportion to the mechanical defect suggests that there was not the diffuse involvement of alveolar and capillary tissues that is found in asbestosis. The findings in two patients with asbestosis (Table 2) are shown for comparison where it will be noted that the ventilatory defect was of the same degree but the diffusion block was considerably greater.

Examination of Exposed Population

When the first case was seen all fellow workers having any comparable exposure were examined,

TABLE 1

RESPIRATORY FUNCTION TESTS

Case	Age (yrs)	Height (in.)	Weight (lb.)	Vital Capacity (ml.)	Residual Volume (ml.)	Total Lung Capacity (ml.)	RV TLC Ratio (%)	Maximum Breathing Capacity (l./min.)	Forced Expiratory Volume (%)	Maximum Inspiratory Flow Rate (l./min.)	Maximum Expiratory Flow Rate (l./min.)	Diffusing Capacity (ml./mm. Hg/min.)
3	46	67	136	2,460 (64)	2,040 (120)	4,500 (82)	45	91 (85)	76	200	200	22·2 (87)
4	39	67	127	3,330 (84)	1,250 (71)	4,580 (80)	27	76 (70)	61	300	200	21·3 (88)
5	65	66	164	2,280 (62)	1,440 (88)	3,720 (70),	39	48 (43)	63	67	120	14·8 (53)
6	52	69	133	3,840 (100)	1,960 (116)	5,800 (105)	34	160 (157)	77	300	400	25·8 (99)
Mean				2,977 (77)	1,672 (99)	4,650 (89)	36 (normal <40%)	94 (89)	69 (normal <70%)	217 (normal >300)	230 (normal >300)	21·0 (82)

Percentages of predicted normal are given in brackets.

TABLE 2

ALUMINIUM LUNG DISEASE AND ASBESTOSIS COMPARED. FIGURES ARE % OF PREDICTED NORMAL (EXCEPT WHERE INDICATED)

Diagnosis	Vital Capacity (%)	Residual Volume (%)	Total Lung Capacity (%)	RV TLC Ratio (%)	Max. Breathing Capacity (%)	Forced Expiratory Volume %	Diffusing Capacity (ml./mm. Hg/min.)
Aluminium fibrosis (four cases)	77	99	89	36	89	69	82%
Asbestosis (two cases)	72	92	78	36 (normal <40%)	90	66 (normal <70%)	44%

Aluminium lung disease and asbestosis compared. In both conditions, there is a reduction in vital capacity without significant airway obstruction. In asbestosis there is in addition a diffusion barrier.

clinically and radiologically, with negative results. Four years later the second case presented and then a search was made for all the men who had ever worked on the process for six months or more. Altogether there were 30 such men; 27 were examined, two refused examination, and one had emigrated. Details are given in Table 3.

Environmental Study

The Process.—Aluminium powders fall into two main types: flake varieties made by stamping the cold metal, and granulated varieties made from molten aluminium. The granulated types, in the main, have larger particles which may be spherical in form, whereas the flake powders are, for the most part, flattened; they have a peculiar "leafing" characteristic and for this reason are widely used in aluminium paints. A specially fine type of "flake" powder, known as "pyro", is composed of very small three-dimensional particles. The Germans used this type of powder to mix with explosives in the second World War and in this country it is used in the manufacture of fireworks. This study is concerned only with aluminium powders of the flake variety and particularly with the pyro type.

The patients all worked in a small factory which produced aluminium powder as a side-line; there were never more than 12 men engaged at one time. The process consisted of treating aluminium foil and stamping it to a coarse powder. From this material both paint and "pyro" powder were made by further stamping which required the addition of grease to prevent the agglomeration of particles. In the manufacture of the paint powder comparatively large quantities of stearin were used; whereas in the manufacture of "pyro" powder the quantity of stearin was kept as low as possible and in 1952 this was largely replaced by mineral oil. Towards the end of the "pyro" process a small quantity of carbon black was added. The stamping of the pyro powder lasted for some 12 hours, which was more than double the time necessary to produce the paint powder. The result was a particularly fine blackish powder. Exposure to high concentrations of dust took place whilst charging and emptying the machines, and during certain weighing and screening processes. Recently men were provided with airline or microfilter respirators but before 1959 no deliberate steps had been taken to prevent the inhalation of dust. The fire and explosion hazard had made the use of exhaust ventilation difficult.

Gravimetric samples of airborne dust were taken with a Hexhlet dust sampler (Wright, 1954). In this very small factory conditions varied considerably from day to day and there were differences between individual workmen depending on the care they took

TABLE 3

SUMMARY OF FINDINGS AMONG 27 MEN EXPOSED TO FINELY POWDERED ALUMINIUM

Case	Age When Seen (yrs)	Other Dusty Jobs	No. of Years Worked With		Years From First Exposure to Onset of Dyspnoea	Dyspnoea	Radiological Changes
			Pyro	Other Aluminium			
1	22	None	2·7	0	2·5	+ + + + +	+ + + + +
2	53	None	3·5	0	3	+ + + + +	+ + + + +
3	44	*1	0	1	—	—	+ + +
4	38	*2	2·5	1·5	—	—	+ +
5	63	None	0·25	8·75	9	+ + +	+ + +
6	51	None	0	3	—	—	+
Others Seen							
i	59	None	0	2 +	—	—	—
ii	29	None	0	3 +	2	+ +	—
iii	48	None	0	4 +	—	—	—
iv	52	None	1	2 +	—	—	—
v	44	None	0	3 +	3	+ +	—
vi	42	None	0	3 +	—	—	—
vii	31	None	0	3 +	—	—	—
viii	44	None	2	1 +	2	+ +	*
ix	54	None	1	3 +	—	—	—
x	41	None	0	1 +	—	—	—
xi	44	None	0	6 +	—	—	—
xii	48	None	0	1 +	—	—	—
xiii	33	*3	2	0	—	—	—
xiv	40	None	2·5	1·5	—	—	—
xv	47	None	0	0·83	—	—	—
xvi	59	*4	1·58	0	—	—	—
xvii	36	None	0·75	0	—	—	—
xviii	43	None	0	1	—	—	—
xix	74	None	Intermittent	5	—	—	—
xx	50	None	0	3	—	—	—
xxi	36	None	0	1·16	—	—	—

*1 Cotton nine years; *2 coal-mine three months; *3 cotton eight years; *4 foundry four years; * Appearances of emphysema.

TABLE 4

SAMPLES TAKEN IN PYRO STAMPING ROOM DURING EMPTYING AND REFILLING OF MACHINES

Workman		No. of Observations	Mean	Standard Deviation
A	Total dust	5	615 mg./cu.m.	69·2 mg./cu.m.
	Respirable dust	5	51 mg./cu.m.	3·9 mg./cu.m.
	Respirable dust as % of total	5	8%	1·0%
B	Total dust	7	685 mg./cu.m.	378·0 mg./cu.m.
	Respirable dust	7	52 mg./cu.m.	20·3 mg./cu.m.
	Respirable dust as % of total	7	8%	2·2%

TABLE 5

APPROXIMATE ESTIMATE OF THE RESPIRABLE ALUMINIUM IN THE ATMOSPHERE AND THE DURATION OF EXPOSURE

Place	Process	Workman	Time (min.)	Mean Respirable Dust (mg./cu.m.)
Stamping room	Empty and refill machines	A	90	51
		B	—	—
Stamping room	Cleaning	A	60	19
		B	60	114
Screening room	Screening	A and B	30	95
Weighing room	Prepare charges	A	30	45
		B	30	84

and the methods they used. Table 4 summarizes the findings in the pyro stamping room during the emptying and refilling of machines, which was the only time they were attended by a workman.

After the powder was removed from the stamping machine it was screened to ensure that it was sufficiently fine. Eleven samples taken in the screening room showed wide variations (as might be expected) with a mean of 95 mg./cu.m. of respirable dust. It was found that the men spent approximately three and a half hours per day on dusty work. Table 5 indicates the time spent by two workmen in the pyro process and the mean concentration of respirable dust to which they were exposed.

Particle size was determined by use of a thermal precipitator. The larger particles appeared as flakes of very irregular shape, and the smaller

particles in the 1-2μ range frequently adhered in small clumps. There were occasional particles of transparent material which may have been stearin. An estimation of the size range of the dust indicated that 70% of the particles were 5μ or less in diameter. The electron microscope showed that all but a few particles were very irregular and flattened. These gave the diffraction pattern of aluminium. The smallest particles giving this pattern measured 0·05μ. Chemical analysis of the dust showed that the free aluminium represented 81·4% (seven determinations ranging between 78% and 87%). The stearin (50% palmitic and 50% stearic acid) represented 0·5%. Approximately 17% was represented by oxides and hydroxides of aluminium. A semi-quantitative spectrographic analysis gave the following approximate values: silicon 0·5%; copper, magnesium, manganese, and iron, approximately 0·1%; beryllium was not detected. The carbon added had an average particle size of 0·029μ and an ultimate composition of 97·9% carbon.

Discussion

The first case of pulmonary fibrosis in an aluminium worker was demonstrated by Baader in 1934 (Doese, 1938). During and after the 1939-45 war many more cases were reported in Germany among men making aluminium powder for ammunition; this experience was summarized by Goralewski (1947) who reported 628 workers from six factories of whom 26% were judged to be uncomplicated cases of pulmonary aluminosis. Other evidence of the incidence of the disease comes from Koelsch (1960), who has been familiar with the industry since 1909. He summarized the German workmen's compensation experience since 1943, when the disease was first recognized for compensation purposes, by saying that 65 cases had been considered of whom 27 were accepted as cases of aluminium lung. Koelsch (1942) attributed the increased incidence during the war to unsatisfactory ventilation imposed by the blackout rules. The main symptom, according to Baader (1949), was dyspnoea; spontaneous pneumothorax frequently occurred. Goralewski (1950) said the same and also mentioned cough and sputum as important symptoms. Sometimes there were no symptoms and scanty findings on percussion and auscultation though the radiological changes were well marked. These changes began with increase of linear striations succeeded by fine foci which tended to aggregate to form cloudy shadows; later the diaphragm showed peaking and the heart shadow became distorted. The pulmonary alveoli became reduced in size by hyalinization and fibrous thickening of the septa. Death often occurred within two years from the onset of symptoms. It is evident that these German authors regard this as an established specific disease. In Japan, Ueda, Mizoi, Maki, Maeda, and Takada (1958) recorded the case of a patient who died three years after he had terminated three years' employment as an aluminium pulverizer; his death was attributed to aluminium dust. In view of the early reports from Germany, Hunter, Milton, Perry, and Thompson (1944) investigated the health of men engaged on grinding propellers made of duralumin (an alloy consisting of 95% aluminium, 4·5% copper, and traces of other metals) with alundum (calcined aluminium oxide 95-97%) wheels. They found no evidence of any disease in the trachea, bronchi, or lungs of these men. We would comment that in Hunter's investigation practically all the fine respirable dust (0·1 mg. per m.^{3} in the general atmosphere and as high as 2·7 mg. per m.^{3} near a polisher) was found to be the alundum abrasive; the aluminium particles were, for the most part, above 7μ in diameter. Crombie, Blaisdell, and MacPherson (1944) investigated 125 workers employed in the Pittsburgh stamp mills of the Aluminium Company of America. The powder was used in the manufacture of paint and ink; the authors made no mention of stearin. Although the workers there had been exposed to aluminium dust for six to 26 years their health was reported to be better than that of the 3,000 other workers employed in the plants. Chest radiographs of all the men taken each year for three years, showed no abnormalities which could be attributed to the inhalation of dust. Assertions that aluminium dust was harmless have been further supported by the work of Denny, Robson, and Irwin (1937), who exposed eight rabbits to an atmosphere containing freshly ground particulate aluminium powder in a concentration averaging 7,000 particles per ml., 12 hours daily for 14 months. They were unable to produce fibrosis or any other significant pulmonary reaction. Crombie *et al.* (1944), prompted by this experimental work, reported remarkable results in the prevention of silicosis by exposing workers to aluminium dust over long periods. They claimed to have shown conclusively that their method of administering aluminium powder was entirely harmless. On the other hand King, Harrison, Mohanty, and Yoganathan (1958) showed that large doses of powdered metallic aluminium injected intratracheally caused a nodular pulmonary fibrosis in rats.

Turning now to the danger from aluminium as fume, Shaver and Riddell (1947) described lung changes found in workers engaged in the manufacture of corundum (aluminium oxide) abrasive.

Bauxite, iron, and coke were fused in an electric furnace at about 2,000°C. During this operation the men were exposed to dense white fume. The cardinal symptom was progressive breathlessness on exertion. Cough with white frothy sputum was usually present. Some cases had spontaneous pneumothorax. The chest radiographs showed widening of the mediastinal shadow; the diaphragm was raised and its outline irregular. There was always abnormal bilateral granular shadowing in the lung fields especially in the upper halves and towards the hilum; coarse shadowing was seen in the more advanced cases which also showed emphysematous changes. In a later paper, Shaver (1948) mentioned the tracheal displacement which we also noted. The pathology was essentially an interstitial lung fibrosis, non-nodular in type, which may be rapidly progressive and accompanied by severe emphysema.

The experience which we have recorded compares closely with those we have quoted. Of the 12 men exposed to fine aluminium powder, two died and two others were affected, and of 15 who worked exclusively on the coarser powder, two had radiological changes but no symptoms. The high incidence of pulmonary fibrosis, for which no other cause could be found, of characteristic pattern and resembling closely cases reported from Germany and Canada, together with the environmental studies, provides strong evidence that the damage to the lungs was caused by the dust. It was apparent that the fine dust was more dangerous than the coarse. Our findings in this respect are in accord with Goralewski (1947) who stated that it was the fine wartime product that was dangerous, contrasted with the coarser powder made in peacetime.

We have found no evidence to show that stearin has been responsible for the fibrosis. In the two fatal cases examinations of frozen sections of lung excluded lipoid pneumonia. Moreover, the coarse powder contained a large amount of stearin (4%) compared with the dangerous pyro powder. Goralewski (1947) said that the aluminium powder used for explosives contained no stearin, in contrast with that made in peacetime, which did contain stearin and which was, in general, innocuous. The probability is that the added stearin actually protects against the damage caused by the aluminium particles. This notion has often been put forward in Germany and we have found no contrary evidence and were very interested to learn that in 1952 in our factory the small amount of stearin added in the manufacture of pyro was halved and the amount made up by adding mineral oil. Case 1 first complained of breathlessness in September, 1953; it is possible that the reduction in the amount of stearin is of great significance. Other substances found in the dust were present in amounts too small to warrant serious consideration as the factor responsible for the fibrosis which we have seen in these cases.

It is concluded that finely divided aluminium was responsible for the lung damage. Acceptance of this conclusion is essential if episodes of the type we have described are to be prevented. We think it probable that the duration of exposure, the size of the particles, the density of the dust, and the presence or absence of stearin as well as individual idiosyncrasy are all concerned in the genesis of this pulmonary fibrosis and that variations of these factors account for the apparently discrepant findings of both experimental and clinical workers in this field.

We are glad of the opportunity to acknowledge the cooperation we have had from the management of the factory and for a grant towards the expenses of the investigation. We acknowledge with gratitude the help of numerous colleagues: Dr. E. D. Gray, Dr. G. B. Locke, and Dr. E. Batley for reporting a "blind trial" of the workmen's chest radiographs with controls; Professor E. J. King for access to reports and translations of literature; Dr. Gordon Knowles for translation of German papers; Mr. S. Roach for advice on dust studies and Dr. Colin Ogilvie for carrying out respiratory function tests on Cases 3, 4, 5, and 6 and for his tables and commentary; Mr. R. A. J. Shelton for spectrographic examination of the aluminium powder and Dr. John Chapman for electron microscopy.

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PULMONARY FIBROSIS IN A WORKER USING AN ALUMINIUM POWDER

BY

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From The Chest Clinic, Pontefract

(RECEIVED FOR PUBLICATION OCTOBER 13, 1960)

A young woman was employed for five years as a "flash filler" in a fireworks factory, using a mixture containing aluminium powder. The powder reached a considerable concentration in the atmosphere of the small room in which the patient worked, after she had swept the room. This was done several times a day.

The patient had developed marked dyspnoea on mild exertion at the end of the five-year period. She was found to have limitation of chest movement with marked tracheal deviation. The radiograph showed the hila to be displaced upwards, a fine granular shadowing throughout the lung fields, and a small pulmonary cyst at the right lung apex. Lung function studies showed a marked reduction in lung volumes and a severely impaired diffusing capacity, while the mechanical function was only slightly below normal. Over the right upper lung lobe a small pneumothorax developed, which gradually resolved.

The similarity of this case to other reported cases in workers with particulate aluminium is noted, as is the view that rheumatoid disease may have had some action in the development of the lung lesion. An alternative diagnosis is considered. Finally, the possibility that personal idiosyncrasy may be responsible for the development of such lung lesions in aluminium workers is mentioned.

There is no general agreement about the effect of aluminium particles on the lungs of workers with this metal. Not only has it been held that powdered aluminium has no harmful effect on the lung, but claims have been made that it may be beneficial in reducing the incidence or severity of certain of the pneumoconioses (Crombie, Blaisdell, and MacPherson, 1944; *Lancet*, 1956). Because of these divergent views any unusual lesion found in the lungs of a worker in any process involving the inhalation of aluminium particles is of interest.

Case Report

The patient, a woman, was 26 years of age when first seen in 1955. At that time she had been unwell for two years, having developed abnormal shortness of breath which had gradually increased in severity. This symptom was accompanied by a slight cough, productive only of a little mucoid sputum. She complained of pain at the right lung base, pleuritic in character, and of tiredness, loss of appetite and of weight, sweating, and irregular menses. The past history contained nothing relevant to the present illness.

Occupational History.—On leaving school the patient undertook domestic service for six months, then for two years worked in a factory, bottling mineral waters. Subsequently for six months she returned to domestic service and then for a period of five years worked in a boot protector factory. Here she was engaged in various capacities. The nature and conditions of her work in this factory make it unlikely that they contributed materially to the development of the lung condition.

At the age of 21 she began work in a fireworks factory where for five years she was employed as a "flash filler". This involved working in a small room, relatively isolated for safety, and filling fireworks by hand, with a mixture of aluminium powder and potassium perchlorate. Much of the mixture was spilled and although the room was not usually dusty the powder reached a considerable concentration in the atmosphere whenever the room was swept. This operation was performed as a safety measure by the patient several times during the working day.

Findings.—The patient was a well-built and well-developed young woman with a little clubbing of the fingers and toes. The trachea was displaced to the right, and the chest movement was poor particularly of the right upper lobe, over which the breath sounds were harsh. A few moist sounds were heard over the left lung apex posteriorly. The postero-anterior radiograph of the chest (Fig. 1) showed both hila displaced upwards,

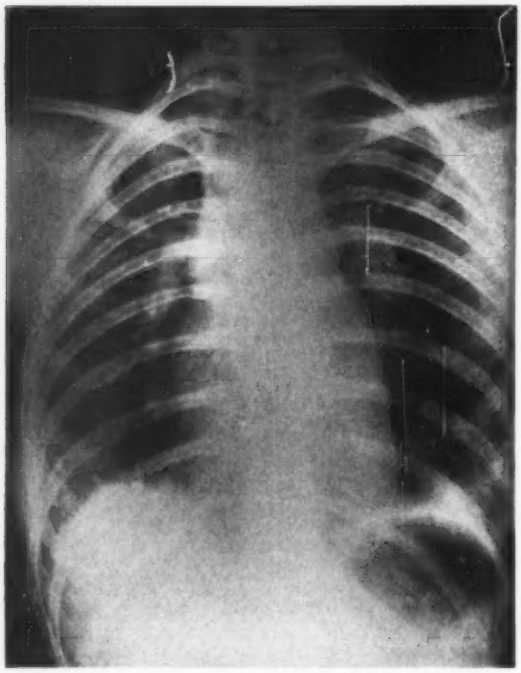

FIG. 1.—Postero-anterior radiograph.

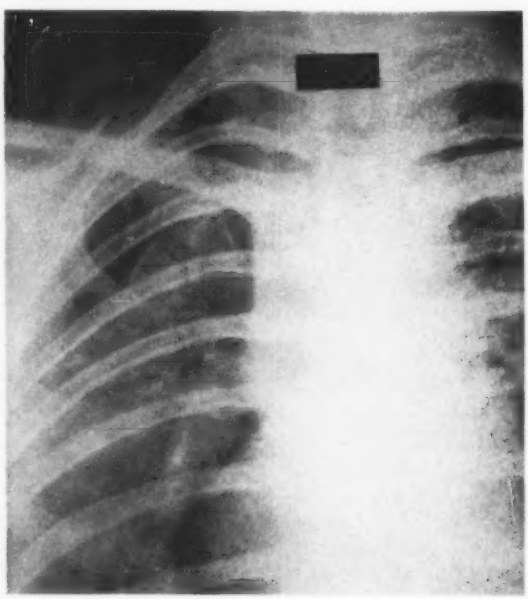

FIG. 2.—Spontaneous pneumothorax over right upper lobe.

the trachea displaced to the right at the thoracic entry, and fine granular shadowing throughout the lung fields. There were diaphragmatic adhesions and calcified lesions at the right lung base. A pulmonary cyst was visible at the extreme right apex with a small right apical effusion. The white cell count and haemoglobin estimations were normal. The erythrocyte sedimentation rate was a little raised at 20 mm. in the first hour (Westergren). The electrocardiograph showed right ventricular hypertrophy. The Wassermann and Kahn tests were negative. In view of the unusual radiological appearance, and the possibility that this might be due to acquired hypersensitivity to aluminium, skin testing with aluminium solutions was undertaken. The result of these tests was negative. Pulmonary function studies showed severe limitation of function due, in the main, to gross impairment of diffusing capacity but also to reduction of all the lung volumes. The values obtained were as follows: total lung capacity 2·97 l.; vital capacity 1·85 l.; maximum voluntary ventilation 56 l./min.; maximum expiratory flow rate 171 l./min. Diffusion capacity was 33% of the predicted normal.

Subsequent Course.—Five months after the patient was first seen, radiography revealed a small pneumothorax at the apex of the right lung (Fig. 2). Films taken at brief intervals showed the pneumothorax to be increasing in size. Because of this, and of the intensity of the fibrosis which the chest radiograph suggested, the prognosis at this time, even on a short-term basis, was not considered good. The patient was kept at rest in bed and the pneumothorax gradually resolved. At the time the pneumothorax was first observed, a guinea-pig, into which a specimen of the patient's sputum had been injected, developed a tuberculous lesion. This was the only occasion over a five-year period on which one of the many samples of the patient's sputum or bronchial secretion yielded a growth of tubercle bacilli. Because of this finding the patient was given a relatively brief course of anti-tuberculous drug treatment. Following these episodes, as a result of which the patient was kept at rest for a period, her general condition improved and she was able to return to work for a while, but subsequently, because of increasing dyspnoea, she has had to stop work. She remains fully ambulant and is able to carry out many household duties.

Four years after the initial examinations the patient complained of pain in the wrists, shoulders, and hands, and soon after developed fusiform swelling of the fingers. The latex screen test and the Rose Waaler reaction were positive (D.A.T. 64). Subsequently, the rheumatoid arthritis has become more marked.

Discussion

The diagnosis of the only case of pulmonary fibrosis in an aluminium worker so far reported in this country (Mitchell, 1959) was confirmed at autopsy, and in the present state of knowledge this is the only satisfactory proof of the diagnosis. Lung biopsy appears to be of doubtful value in the diagnosis of the condition, as the lung sample

obtained may be quite unrepresentative of the lung as a whole. In the present case the procedure was considered but rejected in view of the spontaneous pneumothorax and the possible danger to the patient were such a condition to recur.

Of alternative diagnoses to that of pulmonary fibrosis produced by aluminium particles or aluminium lung disease, pulmonary tuberculosis appears the most probable. There are, however, serious objections to accepting such a diagnosis. The clinical course of the disease and the radiological appearance of the chest are quite atypical of pulmonary tuberculosis in a young woman, there being an absence of significant sputum or haemoptysis at any stage, and an absence of cavitation at the time the patient was first seen despite the presence of an untreated disease process widespread throughout the lungs. Dyspnoea has been the predominant symptom and gross pulmonary fibrosis appears to be the main form of the lesion. In favour of the view that the fibrosis is the result of inhalation of aluminium particles is the similarity of the findings in the case here reported with those reported by Shaver (1948), Goralewski (1947) and Mitchell (1959). In particular, the radiological appearance of this case is very similar in the gross fibrosis, the widening of the upper mediastinal shadow, the granular shadowing, the diaphragmatic adhesions, the presence of bulbous emphysema, and finally the development of a spontaneous pneumothorax, to many of the cases reported by Shaver (personal communication). The particle size of the aluminium powder with which the patient worked varied, but many particles were less than 5μ, *i.e.* sufficiently small to be inhaled into the smallest divisions of the bronchial tree.

It is possible that the patient's rheumatoid condition has had some role in the development of the lung lesion. Cases have been described of patients with rheumatoid disease who developed lung lesions for which no other cause was found (Ellman and Ball, 1948; Price and Skelton, 1956). The radiological appearance of these lesions is, however, completely dissimilar from that seen in the case recorded above. Caplan (1953) first described the radiological opacity which may appear when coalworkers' pneumoconiosis occurs with rheumatoid arthritis. Further cases have been reported of pneumoconiosis modified by rheumatoid disease in occupations other than that of coalworking (Caplan, Cowen, and Gough, 1958; Campbell, 1958; Rickards and Barrett, 1958). It appears possible that the patient's rheumatoid disease may have been a factor in the development or modification of the lung lesions. Such a role could only be demonstrated by histological examination of the lesions (Gough, Rivers, and Seal, 1955; Caplan *et al.*, 1958).

No similar cases have been discovered among the workers at the factory where the patient was employed. This may be explained by the fact that few, if any, of the other workers were employed on this process for a similar length of time; the process was not popular with the employees and one worker could produce a high proportion of the output required; moreover, the turnover of workers at the factory, mainly young women, was fairly high. The use of this mixture in fireworks ceased five years ago.

There remains the problem of whether there may be some personal idiosyncrasy in the production of lung lesions in workers with fine aluminium powder. Goralewski (1947) suggests that the degree of exposure to the powder is the factor of importance in the development of "aluminium lung". Shaver (1948) noted that some workers were exposed for lengthy periods to the fumes of aluminium oxide furnaces without developing any abnormal change in the chest radiograph, while others developed gross changes in a fraction of such time. He mentioned two instances in which both father and son developed the disease.

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BRONCHITIS—SICKNESS ABSENCE IN LONDON TRANSPORT

BY

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From the London Transport Executive

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This study is based on the records of sickness absence of four days or longer attributed to bronchitis among nearly 60,000 London Transport employees during the years 1952 to 1956. The figures support previous observations that there is a close association between the incidence of bronchitis and the occurrence of fog in any year. The bronchitis experience of employees living and working in the north-eastern sector of London is shown to be worse than in other areas of London. The experience of employees in the country belt round London, particularly in the southern sector, is better than in London itself. With the possible exception of conductors, the figures do not suggest that there are occupational factors in the transport industry causing bronchitis.

Since 1948, London Transport have collected and recorded on punched cards data relating to the sickness absence of various groups of employees. Details of the system adopted for the compilation of these data have been published by Spratling and Lloyd (1951) and London Transport Executive (1956). The information available can be subdivided *inter alia*, by reference to sex, age, occupation, place of employment, and diagnosis.

In particular it is possible to select from the records those absences which were attributed to bronchitis. The diagnosis to be recorded is normally obtained from a medical certificate given by the employee's general practitioner. Where questions of terminology or legibility arise, or where the employee is referred to a London Transport Medical Officer on the termination of his absence, it is the Medical Officer who determines the diagnosis to be recorded.

Bronchitis is notoriously difficult to define. Following Reid (1956), we have defined sickness absence due to bronchitis as "absence from work attributed to bronchitis by a general practitioner or by a London Transport Medical Officer". The diagnosis relating to these absences is coded 500, 501, or 502 in accordance with the three-figure International Statistical Classification. Whilst we recognize the difficulties of diagnosis, we do not think these difficulties invalidate comparisons between, for example, different occupational groups or different parts of the London area.

The analysis which follows is restricted to absences lasting four calendar days or longer, because only a minority of shorter spells of absence are supported by a medical certificate. Days of absence after six months (182 days) of continuous absence are excluded from the statistics, because cases of long-term absences pass out of observation at irregular intervals after the first six months of absence as administrative decisions are taken for the retirement or transfer to alternative employment of the individuals concerned. The figures develop, as it were, a ragged edge and are no longer statistically homogeneous. For convenience the statistics are described as "four to 182 days"; they include the first three days of the absences lasting at least four days.

Roundly 10% of the sickness absence recorded for London Transport employees is attributed to bronchitis. Figures published by the Ministry of National Insurance indicate that in the country as a whole bronchitis accounts for roundly 10% of all sickness absence. We think these figures justify the detailed analysis of any data which can throw light on the incidence of bronchitis.

Objects of the Survey

The London Transport sickness-absence records were examined to see whether they would provide information concerning the following:

(*a*) The relative incidence of bronchitis in successive years, bringing to light any peaks in the

incidence of bronchitis and facilitating comparison of other surveys covering restricted periods within the years to be covered by the present study;

(*b*) Differences in the experience of transport workers in different geographical areas of London, for comparison with the results obtained by Reid (1956) in relation to the invaliding rates of postmen;

(*c*) The incidence of bronchitis among transport employees engaged in different jobs, with the possibility of identifying some occupational factor inducing proneness to bronchitis.

As the study proceeded the data suggested the possibility of obtaining provisional answers to the following two specific questions:

(*a*) To what extent does a recent history of recurrent absences from work due to bronchitis permit reliable prognosis of future proneness to bronchitis, with reference to further absences from work or incapacity for the present employment?

(*b*) Is a temporary increase in the level of atmospheric pollution, as in a "smog" period, associated with the *first* manifestations of subsequent histories of chronic bronchitis?

It is hoped to consider these questions in a further paper.

Available Data

The data available consisted of records of sickness absences of four days or longer attributed to bronchitis during the five years 1952 to 1956 among the following groups of London Transport staff:

(*a*) Drivers and male conductors of the central (red) buses, of the trolleybuses, and of the country (green) buses and coaches;

(*b*) Male wages staff engaged on day-to-day maintenance in garages and depots of central buses, trolleybuses and country buses and coaches;

(*c*) Male wages staff of the Railway Operating Department;

(*d*) Male wages staff of the Bus Overhaul Works at Chiswick and Aldenham and of the Trolleybus Overhaul Works at Charlton;

(*e*) Male clerical and technical staff.

The man-years of exposure to risk in broad age-groups and the numbers of absences and calendar days of absence due to bronchitis in each of these groups are shown in Table 1. We have excluded the data for staff at ages 65 and over throughout this study. Data for staff placed in alternative (lighter) work for medical reasons are also excluded.

For the purpose of making the desired comparisons between different years, different geographical areas, and different occupational groups, it was decided to establish a standard with which each subsidiary group of data would be compared in turn. The standard selected for this purpose is the combined experience of all bus and trolleybus drivers and conductors in the years 1952 to 1956. This experience is summarized, in five-year age groups, in Table 2.

Experience in Individual Years

Table 3 shows the number of absences due to bronchitis commencing in each year among each group of staff, expressed as percentages of the combined experience of all bus and trolleybus drivers and conductors shown in Table 2, allowing for the age distribution of each group of staff. Table 4 shows similar results for the number of calendar days of absence.

For the commencement of new absences, it will be seen from Table 3 that 1952 was the worst year for many groups of staff (but not for country bus and coach drivers, conductors, and maintenance

TABLE 1

EXPOSED TO RISK AND ABSENCE FROM WORK DUE TO BRONCHITIS 1952 TO 1956

Group of Staff	Exposed to Risk (man years)					Number of Absences	Number of Calendar Days of Absence*
	Under Age 35	Ages 35-44	Ages 45-54	Ages 55-64	Total		
Central bus drivers	14,435	21,134	21,194	15,988	72,751	2,875	69,420
Central bus conductors	18,864	16,078	11,883	7,626	54,451	2,526	54,317
Trolleybus drivers	4,159	5,479	5,682	2,739	18,059	903	18,287
Trolleybus conductors	5,409	3,980	3,096	1,708	14,193	722	13,552
Country bus and coach drivers	2,806	4,845	5,165	1,603	14,419	410	9,676
Country bus and coach conductors	3,994	3,556	2,518	487	10,555	287	5,802
Central bus maintenance	4,346	4,997	8,471	8,309	26,123	1,222	35,564
Trolleybus maintenance	709	1,478	2,485	2,232	6,904	411	11,293
Country bus and coach maintenance	1,105	1,666	2,210	968	5,949	192	5,846
Railway operating	9,288	7,229	7,839	5,633	29,989	1,301	33,526
Chiswick and Aldenham Works	3,838	4,171	5,416	3,732	17,157	632	14,394
Charlton Works	981	948	1,101	1,199	4,229	127	4,226
Clerical and technical	2,453	1,906	2,775	2,331	9,465	387	7,844
Total	—	—	—	—	284,244	11,995	283,747

* Excluding days of absence after first 182 days.

TABLE 2

BUS, TROLLEYBUS, COUNTRY BUS AND COACH DRIVERS AND CONDUCTORS, 1952 TO 1956
ABSENCE FROM WORK DUE TO BRONCHITIS, 4-182 DAYS

Age Group	Exposure to Risk (man years)	No. of Days Sickness Absence*	Average Annual Duration per Person (days)	No. of Spells	Annual Inception Rate (spells)	Average Length of Spell (days)
-19	105	13	0·124	2	0·019	6·5
20-24	7,015	1,697	0·242	162	0·023	10·5
25-29	17,557	4,298	0·245	335	0·019	12·8
30-34	24,990	6,274	0·251	411	0·016	15·3
35-39	25,188	7,697	0·306	505	0·020	15·2
40-44	29,884	12,493	0·418	722	0·024	17·3
45-49	26,692	17,913	0·671	929	0·035	19·3
50-54	22,846	29,259	1·281	1,289	0·056	22·7
55-59	17,606	43,403	2·465	1,647	0·094	26·4
60-64	12,545	48,007	3·827	1,721	0·137	27·9
All ages	184,428	171,054	—	7,723	—	22·1

* Excluding days of absence after first 182 days.

TABLE 3

NUMBER OF ABSENCES DUE TO BRONCHITIS EXPRESSED AS A PERCENTAGE OF THE STANDARD

Group of Staff	1952	1953	1954	1955	1956	1952-56
Central bus drivers	97	83	75	76	84	83
Central bus conductors	140	105	115	120	121	120
Trolleybus drivers	127	99	108	128	139	120
Trolleybus conductors	136	118	129	139	182	139
Country bus and coach drivers	66	58	60	90	90	74
Country bus and coach conductors	74	92	100	(85)	(110)	92
Central bus maintenance	106	80	54	75	81	80
Trolleybus maintenance	(129)	(106)	(68)	(90)	(103)	99
Country bus and coach maintenance	(70)	(51)	(85)	(76)	(81)	74
Railway operating	125	95	83	97	96	99
Chiswick, Aldenham, and Charlton Works	76	63	60	74	84	72
Clerical and technical	93	78	78	76	80	81
Total	109	88	83	92	99	94

NOTES:—
1. The standard numbers of absences are based on (*a*) the experience for all years of all drivers and conductors combined and (*b*) the exposed-to-risk figure for each group of staff in quinquennial age groups.
2. The figures in parentheses are based on an exposed-to-risk figure of less than 2,000 man years.

TABLE 4

CALENDAR DAYS OF ABSENCE DUE TO BRONCHITIS EXPRESSED AS A PERCENTAGE OF THE STANDARD

Group of Staff	1952	1953	1954	1955	1956	1952-56
Central bus drivers	95	105	70	78	83	86
Central bus conductors	124	136	118	107	112	120
Trolleybus drivers	107	114	95	105	124	109
Trolleybus conductors	114	138	126	98	145	124
Country bus and coach drivers	69	68	66	92	105	81
Country bus and coach conductors	72	109	139	(70)	(100)	98
Central bus maintenance	134	104	70	79	90	96
Trolleybus maintenance	(141)	(150)	(76)	(94)	(97)	112
Country bus and coach maintenance	(93)	(75)	(119)	(99)	(112)	100
Railway operating	138	116	93	97	125	114
Chiswick, Aldenham, and Charlton Works	84	74	62	78	79	76
Clerical and technical	78	65	61	69	79	71
Total	109	108	85	88	99	98

NOTES:—
1. The standard days of absence are based on (*a*) the experience for all years of all drivers and conductors combined and (*b*) the exposed-to-risk figure for each group of staff in quinquennial age groups.
2. The figures in parentheses are based on an exposed-to-risk figure of less than 2,000 man years.

staff). For all groups of staff combined the worst experience was in 1952. There was an exceptionally heavy smog in December of that year. Table 4 shows that there was a relatively high incidence of calendar days of absence in 1952 and 1953. In general terms, after 1952, the commencement of new absences was at the highest level in 1956 (when there was a foggy period in January). The best year overall was 1954.

Experience in Different Geographical Areas

Tables 5 and 6 show the numbers of absences due

to bronchitis among men who were employed in different geographical areas of London. These areas correspond to the divisions which have been defined for the administration of London Transport's road services. The boundaries of each division are indicated in the map (Fig. 1). Table 5 relates to the four central divisions and Table 6 to the two country divisions. Tables 7 and 8 show similar results for the calendar days of absence.

It should be remarked that because of the need for shift working and early and late turns of duty the majority of drivers and conductors lived near their place of employment. It can therefore be assumed that men who were employed in a particular division lived in the corresponding geographical area, but because many bus routes cross central London many of the drivers and conductors spent some part of their working day in one of the other areas. It is calculated that during the period of the study, drivers and conductors spent on average five and three-quarter hours per working day on their vehicle. Maintenance workers mostly worked continuously on the same shift, but the majority of these men also lived near their place of employment and of course did not normally work away from their own garage.

TABLE 5

NUMBER OF ABSENCES DUE TO BRONCHITIS, 1952/56, EXPRESSED AS A PERCENTAGE OF THE STANDARD

Group of Staff	N.E. Division	N.W. Division	S.E. Division	S.W. Division	All Divisions
Central bus drivers	97	80	79	75	83
Central bus conductors	146	112	113	106	120
Trolleybus drivers	135	114	(67)	107	120
Trolleybus conductors	145	141	(161)	(102)	139
Central bus maintenance	87	83	81	66	80
Trolleybus maintenance	90	99	(135)	(120)	99
Total	115	97	92	85	99

NOTES:—
1. The standard numbers of absences are based on (*a*) the combined experience of all drivers and conductors and (*b*) the exposed-to-risk figure for each group of staff in quinquennial age groups.
2. The figures in parentheses are based on an exposed-to-risk figure of less than 2,000 man years.

TABLE 6

NUMBER OF ABSENCES DUE TO BRONCHITIS, 1952/56, EXPRESSED AS A PERCENTAGE OF THE STANDARD

Group of Country Bus and Coach Staff	North Division	South Division	Total
Drivers	89	59	74
Conductors	112	74	92
Maintenance	79	69	74
Total	93	66	79

NOTE.—The standard numbers of absences are based on (*a*) the combined experience of all drivers and conductors and (*b*) the exposed-to-risk figure for each group of staff in quinquennial age groups.

TABLE 8

CALENDAR DAYS OF ABSENCE DUE TO BRONCHITIS, 1952/56, EXPRESSED AS A PERCENTAGE OF THE STANDARD

Group of Country Bus and Coach Staff	North Division	South Division	Total
Drivers	92	71	81
Conductors	120	81	98
Maintenance	108	94	100
Total	102	79	90

NOTE.—The standard days of absence are based on (*a*) the combined experience of all drivers and conductors and (*b*) the exposed-to-risk figure for each group of staff in quinquennial age groups.

TABLE 7

CALENDAR DAYS OF ABSENCE DUE TO BRONCHITIS, 1952/56, EXPRESSED AS A PERCENTAGE OF THE STANDARD

Group of Staff	N.E. Division	N.W. Division	S.E. Division	S.W. Division	All Divisions
Central bus drivers	105	75	84	80	86
Central bus conductors	162	111	109	91	120
Trolleybus drivers	117	110	(150)	105	109
Trolleybus conductors	124	126	(191)	(83)	124
Central bus maintenance	104	90	109	78	96
Trolleybus maintenance	102	118	(141)	(120)	112
Total	120	95	97	85	101

NOTES:—
1. The standard days of absence are based on (*a*) the combined experience of all drivers and conductors and (*b*) the exposed-to-risk figure for each group of staff in quinquennial age groups.
2. The figures in parentheses are based on an exposed-to-risk figure of less than 2,000 man years.

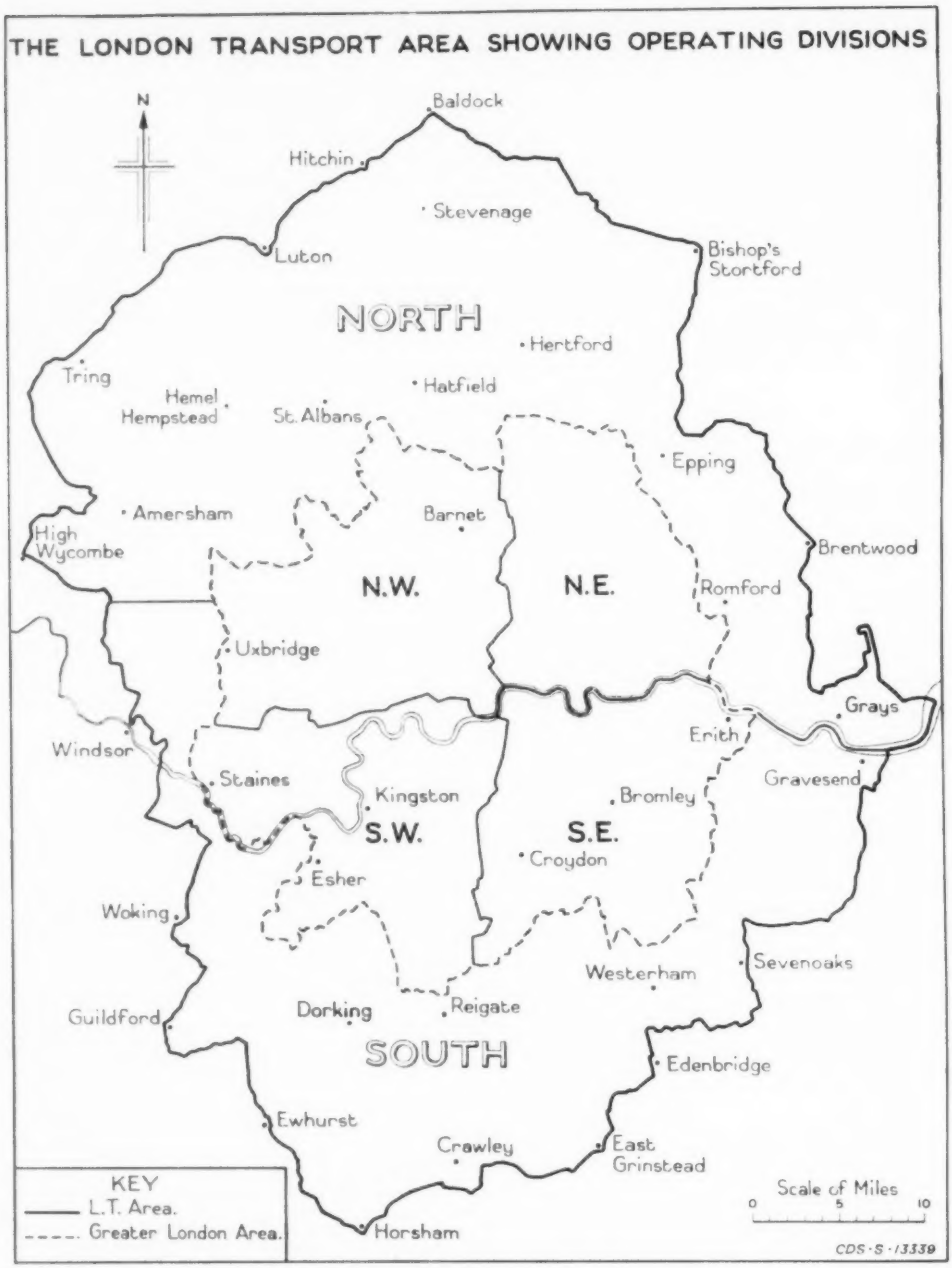

FIG. 1

It is obvious that some of the bus routes originating in each of the divisions are easier or harder than the average for both drivers and conductors to operate. It is thought, however, that the distribution of these routes between the four central divisions to which Tables 5 and 7 relate is sufficiently uniform to permit valid comparisons to be made. Similarly comparisons between the two country

divisions, shown in Tables 6 and 8, are unlikely to be invalidated by any preponderance of easy or hard routes in one of the two divisions.

The work of the maintenance staff is broadly the same in all divisions and in fact the numbers of these staff employed at each garage and depot was proportioned to the numbers of vehicles to be serviced.

It is theoretically possible that there is some geographical difference in smoking habits. The only statistics available on this subject are in Research Paper No. 1 of the Tobacco Manufacturers' Standing Committee (1959). Variations given in that paper between different London areas do not, however, appear to be significant.

It will be seen that of the central divisions the men in the north-east had generally the worst experience and the men in the south-west generally the best. The north-west and south-east divisions show an intermediate experience. Of the two country divisions, the north showed a worse experience than the south. The experience in the northern country division was better than in the north-east and north-west central divisions, though generally worse than in the south-east and south-west central divisions. The experience in the southern country division was on the whole the best of all. As a whole the country bus and coach staff showed a better experience than their counterparts in the central area.

Although the work of the driver and conductor is generally lighter in the country area it is unlikely that this could account for the whole of the better experience of the country area staff compared with the central area staff. This view is supported by the similar difference between maintenance staff in the country and central areas, whose work is little different in character or volume.

The results for the central area broadly confirm the figures given by Reid (1956) relating to the geographical pattern of bronchitis invaliding rates of London postmen, and may reflect the effects upon the pattern of air pollution of the prevailing south-westerly wind, of the relative density of population and hence the relative density of domestic fires, and of the geographical location of industry. The London Transport central divisions are considerably larger than the areas covered by Reid's (1956) study.

The results for the country divisions widen the picture by bringing further new areas under observation. The better experience in the country tends to support the hypothesis that atmospheric pollution is an aetiological factor in bronchitis. The better experience in the southern country division, compared with the northern, suggests that the prevailing wind protects the south and moves the metropolitan pollution northwards. There is also more industry and a greater density of population in the northern country area.

Comparison of Different Occupations

The final columns of Tables 3 and 4 show the sickness-absence experience for all years combined among different groups of staff. The method of recording for each group of staff is the same and it is thought that valid comparisons can be made between the groups. In considering such comparisons, however, it must be remembered that the data relate to sickness absence and not directly to morbidity. The incidence of sickness absence is affected by occupation apart from the incidence of morbidity, because the relative degree of disablement caused by a given clinical condition varies with the physical nature of the work to be performed by the individual. Shift work, too, may give rise to a high level of sickness absence without any variation in the underlying morbidity. For example, it may be much more difficult for a man to come out in the winter in the early morning to some types of job than at a later hour to clerical work. The majority of the staff covered by this survey were engaged in shift work, but this did not apply to clerical and technical staff nor to staff employed at the overhaul factories at Chiswick, Aldenham, and Charlton.

Whilst clerical and technical staff were eligible for sick pay for up to 26 weeks per annum, the majority of staff in the other groups were not covered by sick pay arrangements until December, 1956. Many of the staff in these groups, however, were contributing to Friendly Societies providing sickness benefits.

The role of selection should also be considered. For each occupation there is a process of self-selection in the sense that people do not seek to engage in it unless they consider themselves capable of meeting at least the minimum requirements. Also, they do not remain in it if opportunities arise of other employment which they consider preferable; persistence in a particular occupation is itself a process of continuing self-selection. Superimposed on the self-selection are the employer's selective processes, designed to admit and to retain in his service only those who satisfy physical standards and standards of proficiency and character appropriate to the particular occupation.

Differences between grades in the regulations governing smoking whilst at work are also relevant, particularly as a man who is not able to smoke when he is at work may also be less likely to smoke in his leisure hours, or may at least not smoke heavily. Drivers, conductors, and railway operating staff are not allowed to smoke when on duty, but maintenance and workshop staff are generally allowed to smoke, though there are certain areas where smoking

is forbidden. Clerical and technical staff are allowed to smoke on duty except when in contact with the public.

Drivers and Conductors.—On the central buses, trolleybuses, and country buses alike the conductors experienced more sickness absence due to bronchitis than the drivers. The difference is of roughly the same proportion whether we look at the number of spells of absence or at the number of days of absence from work. This implies that the severity of attacks as measured by length of absence is similar for the two occupations.

Drivers and conductors have broadly similar earnings and social status and similar hours of work. The observed difference in experience of sickness absence due to bronchitis may arise from differences in the nature of their work. The work of the conductor involves more physical effort including frequent movement up and down stairs. The driver works in relatively uniform conditions of temperature and ventilation and is isolated from other people while driving. The conductor is moving about the bus in contact with passengers; this increases his risk of picking up respiratory infections. Previous data (London Transport Executive, 1956) showed that conductors had more absences than drivers because of colds and influenza, especially at younger ages. It is possible that the increased incidence of upper respiratory infections among conductors in their earlier years, compared with drivers, predisposes them to relatively more frequent attacks of bronchitis in later years. To demonstrate this it would be necessary to subdivide the data by length of service and to take special account of drivers who had previously been conductors.

On the other hand the observed differences may also reflect the different standards of medical examination for driving and conducting respectively; in particular, men are sometimes found unfit for driving because they suffer from cough syncope. This is a public safety measure which does not apply to conductors.

There are also differences in the disabling effect of similar clinical conditions for drivers and conductors respectively. The dyspnoea associated with a mild attack of bronchitis would be disabling in the active occupation of conducting a double-deck vehicle but would not necessarily be so in the less physically active occupation of the driver. In addition some conductors experience distress from the tobacco smoke in the upper deck of the vehicle. These considerations suggest that the conductor may be obliged to prolong a spell of absence where a driver would have been able to return to work and, in some cases, to commence a spell of absence from work where a driver would have been able to continue at work. This would mean that the conductor had more long spells of absence than the driver and also more short spells. As shown in Table 3 the conductors had more spells than the drivers, and as mentioned above these figures in combination with Table 4 imply that the average length of absence was similar for the two groups.

Bus and Trolleybus Maintenance Staff.—On the central buses and trolleybuses the maintenance staff experienced fewer absences due to bronchitis than either the drivers or conductors. By contrast the days of absence recorded for maintenance staff were more than among the drivers, though still fewer than among the conductors. This implies that the maintenance staff whilst having fewer spells of absence, experienced more severe attacks of bronchitis when they were absent. On the country buses and coaches the pattern was broadly similar but the experience of maintenance staff was relatively a little worse so that the incidence of absences among the maintenance staff was the same as for drivers, whilst the days of absence were more than among drivers or conductors.

It should be mentioned that about 40% of the maintenance staff were permanently on night work; it is the night shift which is responsible for cleaning the buses. In the period of this study much of the cleaning of the interiors was done by the dusty method of "sweeping-out". More recently, this method has largely been superseded by the use of vacuum cleaners, but this work still continues to be done in the unheated parking area of the garage. The maintenance staff, especially those on the night shift, are also exposed to the maximum concentration of exhaust fumes in the garage at the periods when the buses are running in after service at night, or when they are running out before service in the morning. Incidentally, Commins, Waller, and Lawther (1957) found no evidence that these fumes were carcinogenic.

Unfortunately it was not administratively possible for us to segregate the data for those men mainly on night work from the remainder. It may be supposed, however, that the type of work undertaken at night, and the conditions under which it was performed, explain to some extent why the maintenance staff as a whole experienced somewhat longer spells of absence than the drivers and conductors.

Railway Operating Staff.—The railway operating staff experienced about the same number of absences as drivers and conductors, but rather more days of absence indicating longer spells of absence. The work performed by this group is heterogeneous,

since it includes train crews, signalmen and shunters, and station staff. Train crews consist of motormen (train drivers) and guards on all London Transport railways. Station staff include stationmen (porters), ticket collectors, station foremen, etc. Data for supervisory staff (*e.g.* stationmasters) and for booking clerks are not included. Many more railway staff live and work in the north-eastern and north-western sectors of London than south of the river.

All train crews spend part of their working day above ground and part below. Station staff are liable to work for substantial periods wholly above or wholly below ground but considerable movement between stations does take place.

Workshop Staff.—The experience of workshop staff at Chiswick, Aldenham, and Charlton is relatively favourable in respect of numbers of absences and total days of absence. Chiswick (accounting for some 60% of the whole) is situated in the south-west Operating Division, Aldenham (20%) in the northern country area, and Charlton (20%) in the south-east Division. The staff of these three works live all over London. The type of work and the conditions under which it is done are generally similar to the majority of light/medium engineering factories. There is no shift working. The favourable experience does not seem to be due wholly to geographical factors but probably reflects the more regular working hours and the less variable environmental conditions of workshop staff compared with drivers and conductors.

Clerical and Technical Staff.—The clerical and technical staff also have, for the most part, regular working hours and relatively stable environmental conditions. The majority were employed in large offices in the centre of London but some were dispersed over the whole London Transport area. Generally speaking, these staff live further from their work than the groups already discussed and appear to live in widely scattered residential areas inside and outside London. Clerical and technical staff experienced more spells of absence than the workshop staff but were absent for fewer days in total. There is less physical effort in clerical work than in the work of the other groups discussed and it is therefore not surprising that clerical and technical staff have shorter spells of absence.

Conclusions

This study of the sickness-absence experience, attributed to bronchitis, of five large groups of transport workers in London Transport during the five years 1952-1956 has provided the following information.

The relative incidence of sickness absence due to bronchitis found in all the groups of staff in the successive years supports the observations previously made by many authors that there is a close association between the incidence of bronchitis in any year and the occurrence of dense and prolonged fogs in that year. The particularly severe "smog" of December, 1952 probably contributed to the generally higher incidence among staff working in central London of new cases of bronchitis in 1952 and of the calendar days of absence in 1952 and 1953. This pattern was not repeated in the figures for the workers in the country areas. There was another bad, though less severe, foggy period in January, 1956; in general, there were more new attacks of bronchitis among all the groups of staff in this year than in any other year, except 1952. The year 1956 was also a year of high incidence among the country bus drivers and conductors.

The difference found in this study in the sickness-absence experience attributed to bronchitis of transport workers doing similar types of work in different geographical areas of London supports the findings of Reid (1956) and others. These differences therefore support the conclusion that atmospheric pollution from domestic fires and from industry is responsible for the generally consistent excess of mortality, invaliding rates, and sickness absences attributed to bronchitis, in the north-eastern sector of London compared with the south-western sector, which has been shown in so many different studies.

A special point of interest in the current study is the extension of the areas of observation into the country belt round London. The better experience of country bus drivers, conductors, and maintenance workers in the southern division compared with that of their counterparts in the northern division is striking. As a whole, the country bus staff showed a better experience than their counterparts in the central area.

In the geographical pattern which emerges the experience of the staff in the southern country division can be regarded as approximating to the "normal" in relation to the climatic conditions of south-east England. International comparisons of mortality rates, even when due allowance is made for differences in diagnostic procedure, indicate that the English climate is more conducive to bronchitis than that of most other countries of the world. But in the southern country division the aetiological factors in bronchitis which are subject to human control are probably at a minimum. The experience of staff in the other divisions covered by the survey, however, reflects the varying degrees of metropolitan pollution of the air. Overall, the male employees of London Transport, covered by the survey, suffered an average

of one day of sickness absence per annum attributed to bronchitis. Comparison of the overall figures with those for the southern country division suggests that some 20 or 25% of the overall sickness absence may be ascribed to air pollution. In other words, air pollution in London results in an average of, say, one-fifth of a day's sickness absence per man per year attributed to bronchitis. This result is perhaps rather less striking than might have been expected. It must be remembered, however, that estimates of the total cost to the community of the excess of bronchitis due to air pollution, over and above that due to climate and the minimal pollution in the southern country division, must take account of days of sickness absence beyond the first six months which have been excluded from this survey, as well as permanent disablements and deaths.

The incidence of sickness absence due to bronchitis among transport employees engaged in different jobs does not, with one possible exception, suggest that there are occupational factors in the transport industry causing bronchitis. The marked differences in the incidence and severity of such absence between the various occupations studied appear to be due to the effect of the disease on the capacity for different types of work rather than the effect of the work as an aetiological factor in bronchitis. An engineering worker goes to work with a mild attack of bronchitis which would keep a bus driver away from the wheel of his bus. The bus driver also tends to take longer in convalescence than the clerk because he wants to feel fitter before resuming the more exacting job. It is possible that an exception to this explanation for the variation in the rates occurs with the bus conductors. They have consistently higher rates than the bus drivers in both the central and country areas. Conductors are known to have more upper respiratory infections than drivers and they work in a less sheltered environment, so that the higher rates among the conductors may be due partly to more complications in the form of bronchitis of these upper respiratory infections and partly to an increased proneness to bronchitis because of more frequent respiratory infections in their younger years. Conducting is physically the most strenuous of the occupations studied here, so that, even if infection plays some part in explaining the higher incidence among bus conductors, the disabling effect of even mild attacks of bronchitis would also be most noticeable in this occupation.

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THE CAUSES OF DEATH IN IRON AND STEEL WORKERS (NON-FOUNDRY)

BY

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Few studies have been made of the pathology associated with the iron and steel trades other than foundries. We review here the clinical, occupational, and pathological (post-mortem) findings in 10 grinders and 16 other non-foundry workers in iron and steel. Grinding is evidently a less dangerous trade than it was 100 or even 50 years ago, but silicosis and/or mixed dust fibrosis is still found amongst them. The risk of the onset of pneumoconiosis in other workers in these trades is small, but not absent.

For 15 years or so we have been collecting pathological material to study the causes of death in iron and steel foundry workers, and our observations have been published in two articles (Harding, Gloyne, and McLaughlin, 1950; McLaughlin and Harding, 1956). During the investigation 31 iron and steel workers who had not worked in foundries were included. Of these 10 came from the grinding trades (cutlery, edge tools, and files); five were welders or oxyacetylene cutters (described elsewhere, Harding, McLaughlin, and Doig (1958)); three were forgehands and two were steel sawyers. The remaining 11 cases were single examples of different occupational categories, such as steel roller, steel chipper, sinter plant worker, metal planer, iron miller, iron tube worker, boilermaker, chain blacksmith, file scourer, engineer's turner, and steelworks foreman. All were cases reported to the coroner because of accident, suicide, sudden death, or because a claim for compensation was contemplated by relatives. They thus represent only a (small) proportion of deaths during the period of collection. When one considers the wealth of pathological material which must have been seen in the industrial towns there are surprisingly few published studies which have described the pathology associated with the various trades, with the exception of grinders. And even on this subject, the major work was done early in the last century.

The grinding trades, particularly in Sheffield, have attracted a good deal of attention from the medical profession; the most important early work on the subject was the comparatively little-known book by Calvert Holland, "Diseases of the Lungs from Mechanical Causes" (1843), which dealt in more detail with the subject than C. T. Thackrah's earlier and better-known work "The Effects of the Arts, Trades and Professions" (1831). Holland practised in Sheffield, the home of the grinding industry, whereas Thackrah worked in Leeds and did not have as much first-hand experience of the industry as Holland did. It was the advent of the steam engine and the subsequent Industrial Revolution which brought about and emphasized the dangers of grinding. Calvert Holland points out that "previous to the employment of steam as a propulsive power, all grinding wheels were situated on rivers in the neighbourhood, at a distance varying from two to five miles, and in the midst of scenery exquisitely picturesque and beautiful. The consequence was that, whether the grinder were resident in the country or the town, he had the advantage of an abundance of fresh air and daily exercise. Besides these circumstances, which are well calculated to preserve the animal system in health, he had frequent holidays, from the supply of water being either too great or too small, so that his application was less continuous than under the new system which has none of these interruptions. At the time dry grinding was almost unknown. The introduction of it has been owing to the gradual diminution in the scale of wages. The one process is much more expeditious than the other, and is now (1843) extensively employed". By clinical and autopsy studies Holland clearly distinguished silicosis from tuberculosis and, like Peacock and Greenhow some

of one day of sickness absence per annum attributed to bronchitis. Comparison of the overall figures with those for the southern country division suggests that some 20 or 25% of the overall sickness absence may be ascribed to air pollution. In other words, air pollution in London results in an average of, say, one-fifth of a day's sickness absence per man per year attributed to bronchitis. This result is perhaps rather less striking than might have been expected. It must be remembered, however, that estimates of the total cost to the community of the excess of bronchitis due to air pollution, over and above that due to climate and the minimal pollution in the southern country division, must take account of days of sickness absence beyond the first six months which have been excluded from this survey, as well as permanent disablements and deaths.

The incidence of sickness absence due to bronchitis among transport employees engaged in different jobs does not, with one possible exception, suggest that there are occupational factors in the transport industry causing bronchitis. The marked differences in the incidence and severity of such absence between the various occupations studied appear to be due to the effect of the disease on the capacity for different types of work rather than the effect of the work as an aetiological factor in bronchitis. An engineering worker goes to work with a mild attack of bronchitis which would keep a bus driver away from the wheel of his bus. The bus driver also tends to take longer in convalescence than the clerk because he wants to feel fitter before resuming the more exacting job. It is possible that an exception to this explanation for the variation in the rates occurs with the bus conductors. They have consistently higher rates than the bus drivers in both the central and country areas. Conductors are known to have more upper respiratory infections than drivers and they work in a less sheltered environment, so that the higher rates among the conductors may be due partly to more complications in the form of bronchitis of these upper respiratory infections and partly to an increased proneness to bronchitis because of more frequent respiratory infections in their younger years. Conducting is physically the most strenuous of the occupations studied here, so that, even if infection plays some part in explaining the higher incidence among bus conductors, the disabling effect of even mild attacks of bronchitis would also be most noticeable in this occupation.

We wish to record our thanks to the British Tuberculosis Association and the Association of Industrial Medical Officers for a grant from their joint research fund. This grant paid for part of the expense of the mechanical handling of the 15,000 punched cards analysed in the survey.

We are also indebted to Mr. F. H. Spratling, F.I.A., Chief Establishment Officer, and Dr. L. G. Norman, Chief Medical Officer of London Transport for help and encouragement in the preparation of this paper and to Mr. A. A. Jenkinson and the staff of the Central Record and Actuarial Sections for the machine work and computation involved.

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THE CAUSES OF DEATH IN IRON AND STEEL WORKERS (NON-FOUNDRY)

BY

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Few studies have been made of the pathology associated with the iron and steel trades other than foundries. We review here the clinical, occupational, and pathological (post-mortem) findings in 10 grinders and 16 other non-foundry workers in iron and steel. Grinding is evidently a less dangerous trade than it was 100 or even 50 years ago, but silicosis and/or mixed dust fibrosis is still found amongst them. The risk of the onset of pneumoconiosis in other workers in these trades is small, but not absent.

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20 years later, did so without the help of bacteriology or radiographs. He makes a vigorous attack on Laennec, with whom he had worked in Paris, for denying that the "concrétions osseuses crétacées du poumon" found in workmen in certain dusty trades could possibly be caused by dust.

Arnold Knight in 1844 stated that "in Sheffield there are some 2,500 grinders at work. About 150 are fork grinders; these die between the 28th and 32nd year. The razor grinders, who grind wet, die between the 45th and 50th year". Earlier (1819) he had suggested that criminals might be employed for the process of dry grinding.

Artificial abrasive wheels were introduced about 1910 for hand grinding of razors, and in the next two years the use of these wheels extended to hand-grinding of pen and pocket blades (Law, 1929). Artificial wheels are now used for the grinding of other articles, with the exception of saw grinding in which the sandstone wheel is still used. There are no regulations against the use of sandstone wheels and it has been stated that they are being re-introduced for the grinding of articles other than saws. In machine file grinding artificial abrasive segmented wheels have almost entirely replaced sandstones during the last 20 years.

Grinders

In Table 1 details are given of the pathological lesions and the causes of death in 10 grinders, of whom one worked in the cutlery trade, five in the edge tool, and four in the machine file grinding trade. In all 10 cases, silicosis and/or mixed dust fibrosis were found, mainly in a fairly advanced stage, though the immediate cause of death varied from case to case. Three had massive silicosis; four others had a mixture of moderate silicosis and mixed dust fibrosis; one had moderate silicosis, another moderate mixed dust fibrosis and the tenth case had slight mixed fibrosis and extensive tuberculosis which was the actual cause of death. In only one other case was tuberculosis the cause of death though it was present in two others. In one of these tuberculosis was found in the hilar glands but not in the lungs. Fibrosis due to dust was a definite factor in the cause of death in three cases; in three others it was a doubtful factor because though silicosis and/or mixed dust fibrosis was advanced, the actual cause of death was coronary thrombosis in two and carcinoma of the bronchus in one; and in four others dust fibrosis was not a factor, the causes of death being tuberculosis, coronary thrombosis, operation for carcinoma of the bladder, and carcinoma of the bronchus. Coronary thrombosis was the immediate cause of death in three cases.

Chemical analyses of the lungs were made in only three of these 10 cases. The ash averaged 4·52%; total silica 0·36%; free silica 0·26%; iron (as Fe_2O_3) 1·80% of the weight of the dried lung.

It is a point of interest that generally silicosis was found when the grinders had used sandstones mainly, but when during the course of their working lives they changed to artificial abrasive wheels mixed dust fibrosis was the predominant lesion.

The average age at death of these 10 cases was 58·9 years. In the early 1800's the average age was under 40 years.

Case 1.—C.H., aged 62 at death. He began work in 1903 and worked as an office boy for two years; for nine years he worked as an edge tool grinder (using sandstone wheels) after which he served in the army for four years between 1914 and 1919. On return to civilian life he again worked as an edge tool grinder until 1942 (23 years), again using sandstones. In 1936 he was away from work for six months on account of spontaneous pneumothorax. Tuberculosis was not found. Radiographic examination showed "heavy conglomerate silicosis in both lungs". In 1942 he gave up grinding because it was too heavy for him and he worked as a labourer in a steel works until 1950. He died in April 1951, and autopsy showed the presence of massive silicosis and cor pulmonale.

On naked eye examination the lungs showed massive subapical fibrosis with central necrosis in both lungs. Elsewhere there were scattered, partially calcified, discrete nodules, about 0·25 in. in diameter, decreasing in numbers towards the bases. Bullous marginal emphysema was present. The hilar nodes were large, very hard, and partially calcified.

On microscopic examination conglomerate nodular

TABLE 1
GRINDERS

Trade Group	No.	Pneumoconiosis as Cause of Death			Pulmonary Tuberculosis	Carcinoma Bronchus	Coronary Thrombosis
		Factor	Doubtful	Not			
Edge tool	5	2	2	1	0	1	1
Machine file	4	1	1	2	3	1	2
Cutlery	1	0	0	1	1	0	0
Total	10	3	3	4	4	2	3

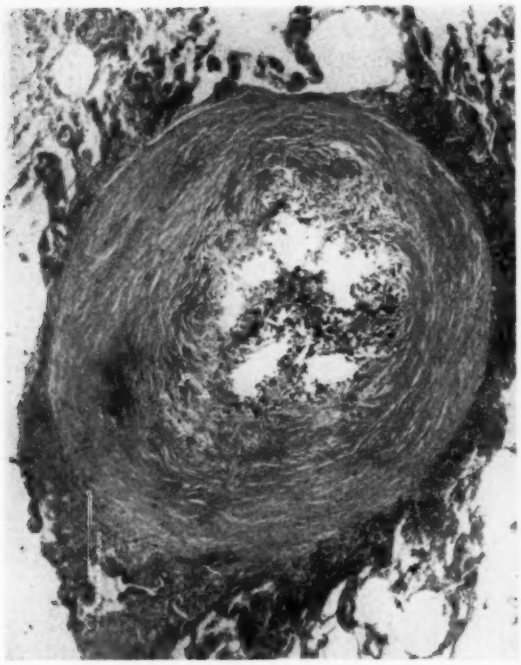

FIG. 1.—Silicotic nodule with ischaemic necrosis in its centre (Case 1). (Haematoxylin and Eosin × 6.)

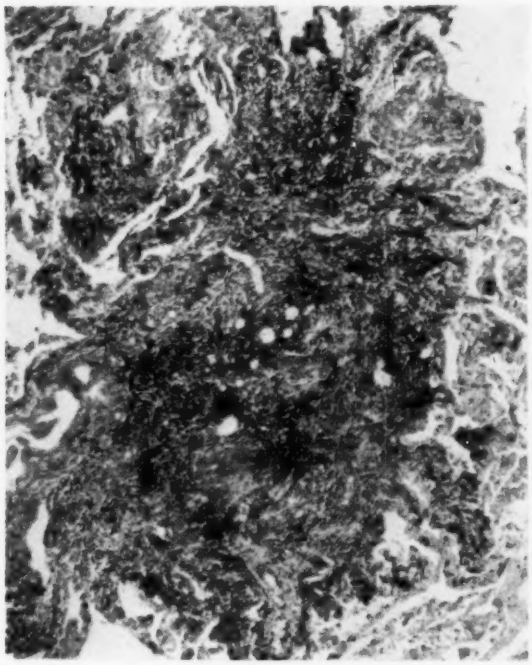

FIG. 2.—Mixed dust fibrosis (Case 1). (Haematoxylin and Eosin × 6.)

silicosis (Fig. 1) was present, with slight calcification and breaking down in places. There were also areas of mixed dust fibrosis (Fig. 2). No tuberculosis was seen.

CHEMICAL ANALYSIS.—Ash 3·76%; total silica 0·59%; free silica 0·37%; iron (as Fe_2O_3) 1·37% of dried weight of the lung.

COMMENT.—Massive partially calcified silicosis with some mixed dust fibrosis in an edge tool grinder who had been exposed 32 years to the dust of sandstone wheels.

Case 2.—G.S., aged 66 at death. He began work in 1900 at 14 years of age and worked until 1914 as an edge tool grinder, using sandstone wheels. From 1914-19 he was on army service. After the war he worked at the same factory as a sandstone edge tool grinder until 1934 when he was obliged to stop work on account of lung trouble coupled with rheumatoid arthritis. His general condition gradually deteriorated and in 1940 he was admitted to hospital where he remained until his death in February, 1951. He had thus been exposed to the dust of sandstone grinding wheels for 29 years and was unable to work after 48 years of age, though he did not die until 17 years later.

On naked eye examination, there were pleural adhesions over the whole of both lungs. Massive grey-black very hard fibrosis was present at both apices extending down for some 2 in., where it became nodular. The mass at the right apex showed some central necrosis, but there was no evident tuberculosis. Black nodules with grey markings up to 0·25 in. in diameter were scattered throughout both lungs in numbers decreasing towards the bases.

On microscopic examination conglomerate and discrete silicosis was seen. Necrosis of the massive fibrosis was present, as well as calcification in the lungs and the hilar lymph nodes. In addition there was bronchitis and oedema. Neither tuberculosis nor Caplan's nodules were seen.

CHEMICAL ANALYSIS.—Ash 8·56%; total silica 0·24%; free silica 0·16% and iron (as Fe_2O_3) 0·19% of the dried weight of the lung.

COMMENT.—An edge tool grinder using sandstone wheels for 29 years died from massive silicosis without tuberculosis at the age of 66, though he had been totally disabled since 48 years of age.

Of the six grinders (five edge tool and one cutlery) four had extensive or moderate silicosis or mixed dust fibrosis, one had slight silicosis and mixed dust fibrosis, and one had only very slight mixed dust fibrosis. This last man died of tuberculosis. Tuberculous lesions were found in the hilar lymph nodes in another case, but not in the lungs. The other four cases showed no evidence of tuberculosis. In two cases fibrosis due to dust was a definite factor in the deaths, in two it was doubtfully a factor (one coronary thrombosis, one carcinoma of bronchus)

and in two it was not a factor (one operation for partial cystectomy, one tuberculosis). Chemical analyses were made on only three. Lung ash averaged 4·52%; total silica 0·36%; free silica 0·26%, iron (as Fe_2O_3) 1·80%.

Machine File Grinders

These workers grind files in machines, fitted with sandstone wheels, running in tanks of water. In the last 20 years or so abrasive wheels have been used. They do not have to bend over the grinding wheels as closely as do the grinders of edge tools. The four cases in the series had been employed on the same job all their working lives. Two of them died at 64 years of age, one at 61, and the fourth at 41 years of age. All showed silicotic nodules and mixed dust fibrosis, in moderate degree. Three of them had pulmonary tuberculosis, inactive in one. Two died from coronary thrombosis; one had bronchiectasis; two had generalized fine emphysema; two had focal emphysema of slight degree. On chemical analysis the average lung ash was 3·01% (ranging from 1·95 to 3·80); total silica 0·34% (0·28-0·55); free silica 0·26% (0·13-0·41); iron (as Fe_2O_3) 0·44% (0·39-0·61). Pneumoconiosis was considered to be a factor in the death of one, a doubtful factor in one, and not a factor in two, who died from coronary thrombosis.

Case 3.—E.B. died at age of 41. All his working life was spent at one factory as a machine file grinder. He became ill with symptoms of cough, dyspnoea, and expectoration at 39 years of age, and died two years later from silicosis and tuberculosis complicated by bronchiectasis.

On naked eye examination the left lung showed moderate generalized emphysema, with scattered pigmented areas, most of them soft, but a few hard nodules up to 2 in. in diameter. The right lung was small with a dense pleura, tuberculosis in right upper lobe, and in addition there were present hard conglomerate nodules. At the right base there was an area of bronchiectasis.

Microscopical examination (Fig. 3) showed silicotic and tuberculous nodules, with some areas of mixed dust fibrosis. Generalized fine emphysema (and ? focal) was also present.

CHEMICAL ANALYSIS.—Right lung: ash 3·80%; total silica 0·55%; free silica 0·41%; Fe_2O_3 0·39% and left lung: ash 2·59%; total silica 0·42%; free silica 0·25%; Fe_2O_3 0·51% of the dried weight of the lung.

COMMENT.—A machine file grinder who died at 41 years of age after 24 years exposure. Death was due to pneumoconiosis with cor pulmonale, with slight tuberculosis and bronchiectasis. Chemical analysis showed that the right lung had retained more dust with the exception of iron than the left.

Case 4.—H.H., 61 years of age at death, was a machine file grinder all his working life (about 47 years) at one firm. He died suddenly at home in January, 1950 and at autopsy death was found to be due to coronary thrombosis.

On naked eye examination of the lungs, the pleural lymphatic markings were seen to be exaggerated. There were hard black nodules throughout the lungs, but more in the upper lobes, mainly small (1-2 mm.); a few nodules were larger. There was also generalized fine emphysema and pulmonary congestion. No tuberculosis was present. The hilar nodes were large and black with grey hard areas.

Microscopical examination showed discrete silicotic nodules (Fig. 4) with areas of mixed dust fibrosis (Fig. 5), associated with focal emphysema. In addition there was congestion and oedema of the lungs. In the hilar lymph nodes were aggregates of silicotic nodules.

CHEMICAL ANALYSIS.—Ash 1·95%, total silica 0·18%, free silica 0·13%, and iron (as Fe_2O_3) 0·46%, of the dried weight of the lungs.

COMMENT.—A machine file grinder who died at 61 years of age from coronary thrombosis. Silicosis and mixed dust fibrosis were present in the lungs. Dust was not a factor in the immediate cause of death.

Case 5.—J.H.C. died at the age of 64. He was a machine file grinder who had used sandstone all his working life (approximately 50 years) at one firm. Had suffered from a cough and dyspnoea for some years before his death, and three months before had been away from work for five weeks on account of "pleurisy". He died suddenly at home and autopsy showed that the cause of death was coronary thrombosis. There was an old thrombus in the left coronary artery and a recent one in the right. The left ventricle was thinned and fibrotic at the apex.

Examination of the lungs showed old pleural adhesions on both sides especially over the apices. In the apical regions also there were masses of fibrous tissue enclosing dry partially calcified caseous material. Throughout the lungs, were small, very hard calcified nodules. In addition there was focal emphysema.

On microscopical examination both mixed dust fibrosis and silicotic nodules were seen. The apical masses were composed of silico-tuberculosis. Fig. 6 shows an area where there is a conjunction of silicotic nodules and mixed dust fibrosis.

COMMENT.—A machine file grinder of 50 years exposure who, though he died from coronary thrombosis, had well-marked silico-tuberculosis and mixed dust fibrosis.

Engineering Machine Shop Workers

Post-mortem examinations were conducted on seven men (two steel sawyers, a metal planer, an iron miller, an engineer's turner, a magnet inspector, and a boilermaker) whose ages ranged from 48 to 69 years with an average of 59·3, and most of whom had been employed on the same job for 30 or more years.

FIG. 3

FIG. 4

FIG. 3.—Conglomerate silicotic nodules. Bone formation in hyaline fibrous tissue (Case 3). (Haematoxylin and Eosin × 6.)

FIG. 4.—Silicotic nodule(s) (Case 4). (Haematoxylin and Eosin × 6.)

FIG. 5.—Mixed dust fibrosis: focal emphysema (Case 4). (Haematoxylin and Eosin. × 8.)

FIG. 6.—Conjunction of silicotic nodule and mixed dust fibrosis (Case 5). (Haematoxylin and Eosin × 6.)

FIG. 5

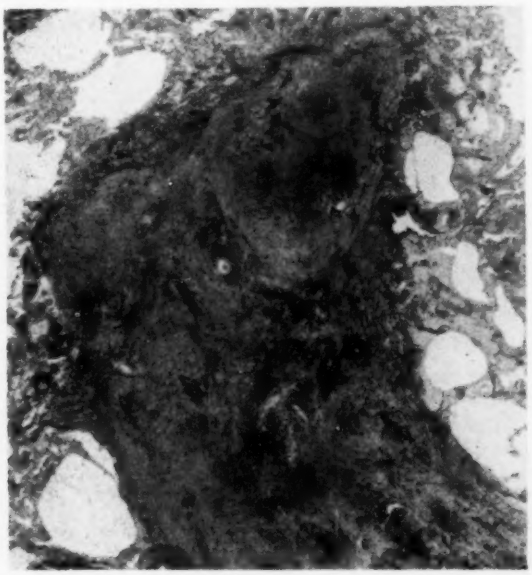

FIG. 6

TABLE 2
OTHER NON-FOUNDRY WORKERS

Trade Group	No.	Pneumoconiosis as Cause of Death			Pulmonary Tuberculosis	Carcinoma Bronchus	Coronary Thrombosis
		Factor	Doubtful	Not			
Engineering machine shop	7	0	1	6	1	0	0
Forgehands	4	1	0	3	1	0	1
Steel roller	1	0	0	1	0	0	1
Sinter plant worker	1	0	0	1	0	0	0
File scourer	1	0	0	1	1	0	0
Steel chipper	1	0	0	1	0	0	1
Fireman	1	0	0	1	0	0	1
Total	16	1	1	14	3	0	4

Four of them showed slight or very slight mixed dust fibrosis, one a doubtful fibrosis, and two no fibrosis. In six, pneumoconiosis was not a factor in death from hypertension, uraemia from chronic nephritis, cor pulmonale due to acute or chronic bronchitis, acute bronchopneumonia, accident, and suicide. In one case, the boilermaker, it was a doubtful factor in death that resulted from an extreme degree of atrophic emphysema. Chemical analysis of five of the lungs gave as an average of the dried weight of the lung, ash 2·37%, total silica 0·25%, free silica 0·14%, and iron (as Fe_2O_3) 0·49%.

This small series suggests that pneumoconiosis is not an important risk in this part of the industry.

Case 6.—D.W.B. worked as a boiler maker after leaving school: he never cleaned boilers. For his last 12 years at work he was a foreman, inspecting boilers. He gave up work several months before he died at the age of 48.

The lungs were received by us after fixation and some cutting. They showed extreme emphysema of atrophic type with bullae at the apices and anterior margins. The cut surfaces were black but without definite fibrosis. The hilar lymph nodes were moderately enlarged, black but fairly soft.

Microscopically there was slight mixed dust fibrosis: much of the dust was in collections of phagocytes in some alveoli. Emphysema was a notable feature, generalized and not evidently focal. The hilar lymph nodes contained only a little dust and showed no fibrosis.

CHEMICAL ANALYSIS.—Ash 2·87, total silica 0·31, free silica 0·15, and iron, expressed as Fe_2O_3, 0·93, expressed as percentages of dried weight of the lung.

COMMENT.—Minimal pneumoconiosis and marked general emphysema in a man of 48 years of age who had had 34 years' experience of boilermaking. It is doubtful whether pneumoconiosis was a factor in his death.

Forgehands

Three forgehands and a chain blacksmith aged 48, 43, 54, and 67 years respectively were encountered (Table 2). One had silico-tuberculosis, and pneumoconiosis was considered to have been a factor in his death. Slight mixed dust fibrosis was present in the lungs of the other three cases, but was not considered a factor in their deaths, from accident, coronary thrombosis, and acute bronchopneumonia following chronic bronchitis. The average chemical findings in the three who did not have tuberculosis, expressed as a percentage of weight of dried lung, were ash 2·87, total silica 0·28, free silica 0·19, and iron (as Fe_2O_3) 0·32.

Case 7.—A.H.B. entered the forging shop soon after leaving school and remained there the rest of his life, rising in responsibility to foreman forgehand. He worked on the same hammer for his last 10 years. He died at the age of 43 years as the result of an accident at work, when the handle of a tongs was driven into his pelvis tearing the right iliac artery.

To the naked eye the lungs showed non-palpable black patches and spots on the pleurae, and small non-palpable black areas scattered throughout the lungs. Microscopically there was very slight mixed dust fibrosis in the lungs (Fig. 7), and pigmentation without fibrosis in hilar lymph nodes.

CHEMICAL ANALYSIS. Ash 2·55, total silica 0·15, free silica 0·14, and iron (as Fe_2O_3) 0·39, all as percentages of the weight of dried lung.

COMMENT.—Very slight mixed dust fibrosis was not a factor in the death by accident of a man employed as a forgehand for 29 years.

Miscellaneous Workmen

Case 8.—A sandblaster and scourer of files*, who was 54 when he died, had done this job all his working life for one firm. He was ill with chest trouble four years before he died and did not return to work. He was examined by the Pneumoconiosis Medical Panel who refused a certificate. His lungs showed cavitation and pigmented fibrosis at both apices, involving much of the

* The use of sand in blasting was prohibited by the Blasting of Castings (and other Articles) Regulations, 1949, but an exemption has been granted for the sandblasting of files. The process is almost entirely enclosed; a jet of steam is applied at the same time as the sand, and the enclosure is under exhaust ventilation. There is little or no risk of the inhalation of dust.

upper lobes. Patches of caseous pneumonia were seen in the lower lobes. The remainder of the lower lobes showed only slight focal pigmentation and no sign of fibrosis. Microscopically there was tuberculosis of varying age: there was a fair amount of pigment in the more fibrous areas, but all the fibrosis seemed to be of tuberculous origin and it was doubtful whether there was any true pneumoconiosis.

CHEMICAL ANALYSIS.—Ash 1·68, total silica 0·14, free silica 0·07 and iron (as Fe_2O_3) 0·14, all as percentages of weight of dried lung.

Case 9.—A steel chipper*, aged 68 years, worked for one firm for 22 years: his firm say that his occupation would not have exposed him to dust. He never complained of ill health. He collapsed and died in the street, and after an autopsy his death was recorded as due to coronary thrombosis. His lungs showed marked generalized emphysema with bullae: they were much pigmented but the aggregates were only doubtfully palpable. Microscopically there were small aggregates of very dense pigment with very little fibrosis. Incinerated sections showed that much of the pigment was iron: incinerated and acid-treated sections showed hardly any doubly refractile material.

CHEMICAL ANALYSIS.—Ash 3·72, total silica 0·23, free silica 0·10, iron (as Fe_2O_3) 2·40, as percentages of weight of dried lung.

Case 10.—A sinter plant worker, aged 64 years, was a collier between the ages of 14 and 32. From then he was employed continuously in a sinter plant, where he collapsed and died suddenly. His death was stated to be due to "chronic aortic endocarditis". The lungs showed tiny black areas of focal emphysema present mainly in the upper lobes, but no nodules were palpable with certainty. Microscopically there was slight mixed dust fibrosis and focal emphysema: whorled fibrous nodules were present in the hilar nodes.

CHEMICAL ANALYSIS.—Ash 1·33, total silica 0·13, free silica 0·05, iron (as Fe_2O_3) 0·53, expressed as percentages of weight of dried lung.

Case 11.—A steel roller died of coronary thrombosis. Only a large section of his lung was available for study. This showed slight marginal emphysema. Using a hand lens it was possible to see tiny areas of mixed dust fibrosis not apparent to the naked eye.

Case 12.—A steel works fireman died at 66 years of age. He had been employed as a tram driver before working for 10 years at cold sawing of steel bars. After this he became a fireman for 20 years. Seven years before he died he had an haemoptysis the cause of which was found to be mitral stenosis. Post-mortem examination showed "mitral stenosis, coronary atherosclerosis, and fibrosis of the right ventricle. He also had a gastric ulcer".

* The term "chipper" is used in the U.S.A. as a synonym for the terms "fettler" and "dresser" employed in this country. This workman was not fettling steel castings.

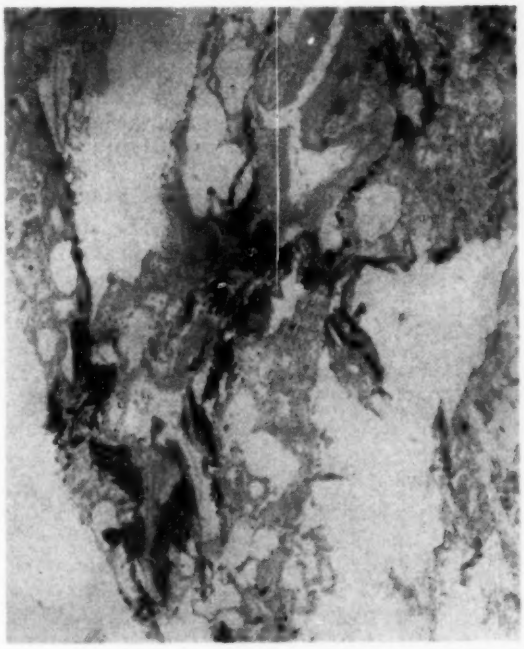

FIG. 7.—Slight mixed dust fibrosis: focal emphysema (Case 7). (Haematoxylin and Eosin × 6.)

A large section of the lung showed emphysema but no fibrotic nodules. Microscopically the lungs showed no fibrosis; some pigment was seen in intra-alveolar phagocytes.

CHEMICAL ANALYSIS.—Ash 2·91, total silica 0·04, free silica 0·05, and iron (as Fe_2O_3) 0·87, as percentages of the dried weight of the lung.

These five workmen showed only slight or no pneumoconiosis, which was not a factor in the death of any of them. Two died of coronary thrombosis, one of chronic aortic endocarditis, one of mitral stenosis, and one of pulmonary tuberculosis.

Discussion

Grinding is evidently a less dangerous trade than it was 50 or 100 years ago, and grinders live longer. This improvement in the health of grinders results from a combination of many factors, some general to the population and some affecting the particular employment. Among the latter are the replacement of sandstone by artificial grindstones in many works, provision of exhaust ventilation, and a general raising of the standard of housekeeping in works.

Nevertheless silicosis and/or mixed dust fibrosis still affects grinders as shown in the cases listed above. Classical whorled silicotic nodules are found in men who have used sandstone grinding wheels,

while mixed dust fibrosis is the lesion found in those using artificial stones. More remains to be done to improve the working conditions of grinders.

The position is much better in respect of other non-foundry workers in the iron and steel industries. In only one of the 16 cases reported here was pneumoconiosis considered to have been a major factor in the death of a workman, and he had pulmonary tuberculosis. The working conditions of the men in this group vary greatly; many of them have a quite insignificant risk of pneumoconiosis, but some of them have a risk that is of a lesser degree than that of foundry workers.

The photomicrographs were prepared by Mr. R. Conroy.

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A STUDY OF ASPERGILLUS SPORES IN THE ATMOSPHERE OF A MODERN MILL

BY

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A study has been made of the atmospheric pollution by aspergillus spores of a large animal provender mill in which various grains are unloaded, stored, and processed, and a comparison has been made with the degree of pollution of the urban atmosphere in the neighbourhood. The catch-rate of the spores in the normal working atmosphere of the mill has been found to be 30 times higher than that obtained in the urban atmosphere, and for this reason the health record of a group of operatives has been considered with particular reference to the occurrence of pulmonary aspergillosis. Despite the risk of exposure within the mill no evidence has been found of an increased liability to develop the disease.

The particular groups of aspergilli isolated by culture during this study have all been reported to have been associated with aspergillosis in man, and the relevant papers give evidence of a pathogenic rather than a saprophytic role. The study therefore provides quantitative data relating atmospheric spore content and the risk of pulmonary infection in man, a subject which as yet has received little attention.

In this study it has been found that of all the grains handled in the mill, maize is associated with the highest degree of contamination, so that the aspergillus spores in the atmosphere of the mill may have originated chiefly from this source.

The association between aspergillosis and grain has been known since Dieulafoy, Chantemesse, and Widal (1890) described the disease as an occupational hazard of pigeon-crammers. Reports of particular interest are those of cases in which the fungus has been isolated from human lesions and identified, and in which evidence is given both of the pathogenic role of the fungus and of the probable mode of infection. Such reports related to *A. nidulans* (Holden, 1915), *A. versicolor* (Steele, 1926), *A. flavus* (Wahl, 1928), *A. fumigatus* (Hertzog, Smith, and Goblin, 1949), and *A. niger* (Utz, German, Louria, Emmons, and Bartter, 1959), while *A. clavatus* was included by Hinson, Moon, and Plummer (1952). *A. glaucus* has been reported only infrequently (Cawley, 1947). It seems strange, therefore, that those who have specially studied pulmonary disease, which occurs in men working in contact with grain, find little to say on aspergillosis. Wohlhueter, Kleitz, Kraft, and Mourot (1940) studied chest disease in 10 millers and bakers, and in these the lesions were associated with silica dust rather than aspergillus spores. Similarly, Dunner, Hermon, and Bagnall (1946), who studied the lung changes in the grain dockers of Hull, found no aspergillosis. Dunner, Hardy, Nakielny, Robinson, and Smart (1958) examined 31 men who habitually handled grains of all sorts and in none of these was there evidence of pulmonary mycosis. There is no doubt that moulds flourish in grain, and that persons exposed to grain sometimes develop pulmonary aspergillosis; nevertheless, such an event seems to be rare, and there is only one recorded case of compensation being awarded to a man who developed aspergillosis after working with hay, grain, and corn for more than 20 years (Ford *v.* Union Stock Yards, 1942). It is probable that grain dockers are scarcely exposed to the dust, and this may account for the absence of aspergillosis in these people, although Dunner *et al.* (1946) suggest that where pneumatic elevators are not used the amount of dust in the holds may be considerable. Referring to the epidemiology of the disease Ainsworth and Austwick (1959) considered that all mammalian aspergillosis was probably a primary pulmonary disease contracted by inhalation of large

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numbers of fungal spores, and that the quantitative relation of spores to infection appeared to be the key to the epidemiology and pathology of aspergillosis. This opinion is not new for it was expressed by Raether (1912) who stated that man was relatively immune to aspergillus infections and that a large infecting dose was necessary, and by Coe (1945) who suggested that "the principal factor in the pathogenesis of the disease in man seems to be exposure to repeated massive dosage".

Nothing has been found in the literature of work which provides quantitative data on this subject. The present study has been undertaken in order to determine (a) the frequency of occurrence of aspergillus spores in the atmosphere of an animal provender mill, and to compare this frequency with that found by similar means at selected sites elsewhere in the neighbourhood at the same time of year; (b) whether there is any association between the presence of aspergillus spores in the atmosphere and the type of grain being moved at the mill; and (c) the existence of any associated liability of the mill operatives to develop pulmonary aspergillosis.

Method

Petri-dishes 9 cm. in diameter and containing Sabouraud's medium were exposed to the atmosphere at selected sites for known periods of time. The cultures were incubated at room temperature regulated as far as possible to 22°C. and the total number of colonies growing on each plate was counted after four days, at which time seedling colonies would not be apparent. Incubation was continued until the seventh day when all colonies of aspergilli were counted, and a percentage figure calculated.

This was the basis of the counts, but in practice it was found impossible to keep strictly to the times. The number of colonies growing on each plate varied considerably, depending on several factors including exposure time and spore concentration, and the morphological characteristics of colonies varied according to the degree of crowding on the plate. Sometimes the aerial mycelium was produced on or before the fourth day, at which time any recognizable aspergilli were noted, while on occasions its production was delayed until the seventh day. On the other hand, in preliminary experiments it was found difficult to make an accurate total count on the seventh day because of colonies becoming contiguous. For these reasons it was found best to make the total count on the fourth day and to count the aspergilli when recognition could be certain. To begin with all suspected colonies were identified by means of Sabouraud slide cultures incubated at room temperature. Aspergilli were later identified by means of a $\times 12$ hand lens, and slide cultures were employed only when the appearance was atypical.

In addition to the defects of the method already mentioned it was recognized that the results were influenced by several other factors. When the total number of colonies was 200 or more per plate the count became difficult and the error increased, while, when the total colonies were few, it was impossible to calculate an accurate percentage figure for the aspergilli. There was also the inaccuracy associated with the periodic growth of spreading moulds which in preliminary experiments rapidly covered the whole plate. This difficulty was overcome by inspecting the closed plates every day and by excising the colonies before they became too large. It was necessary only rarely, to excise such a colony before the third day and at the time of excision all the other colonies included in the zone were counted and added to the total count. Aspergilli in the zone were of course not recognized, but this source of error tended to diminish rather than to increase the aspergillus count. It was found that spreading moulds were not as common as might have been expected; nevertheless, several experiments were rendered valueless and the results were not recorded.

It is not easy to determine with consistent accuracy the spore content of a number of greatly different air samples. The method employed here has the advantage of simplicity and the importance of this outweighs the significance of its obvious defects.

The Mill

In order to understand the type of air samples which were examined a brief description is given of the mill where the experiments were performed.

All the grain is withdrawn from the ships by means of pneumatic elevators (Fig. 1) and is passed on to a moving belt in a gantry whence the grain is conveyed to the main silo. During the process of unloading a ship a large quantity of dust is produced in the gantry especially at the point where grain is transferred from the elevator to the conveyor belt.

Operatives are not constantly employed at this site, but while the elevator is in action respiration is impossible for any length of time without some protection. During preliminary experiments plates were exposed at the head of the elevator, but the conditions were unbearable and the plates were too heavily inoculated; because of these difficulties all other plates exposed in the gantry were opened at some distance along the conveyor (Fig. 2).

The silo comprises numerous large store-bins and has a total capacity of 20,000 tons of grain. The grain is transferred from ship to silo or from one compartment to another within the silo itself by means of conveyor belts; these traverse the roof of the silo and empty grain by means of shutes into individual bins. Usually, but not always, a dust extractor is placed near the shute, and a moderate amount of dust is present at these sites and in the general atmosphere of the silo-top. For this study plates were exposed at the points where grain disappeared down the shutes.

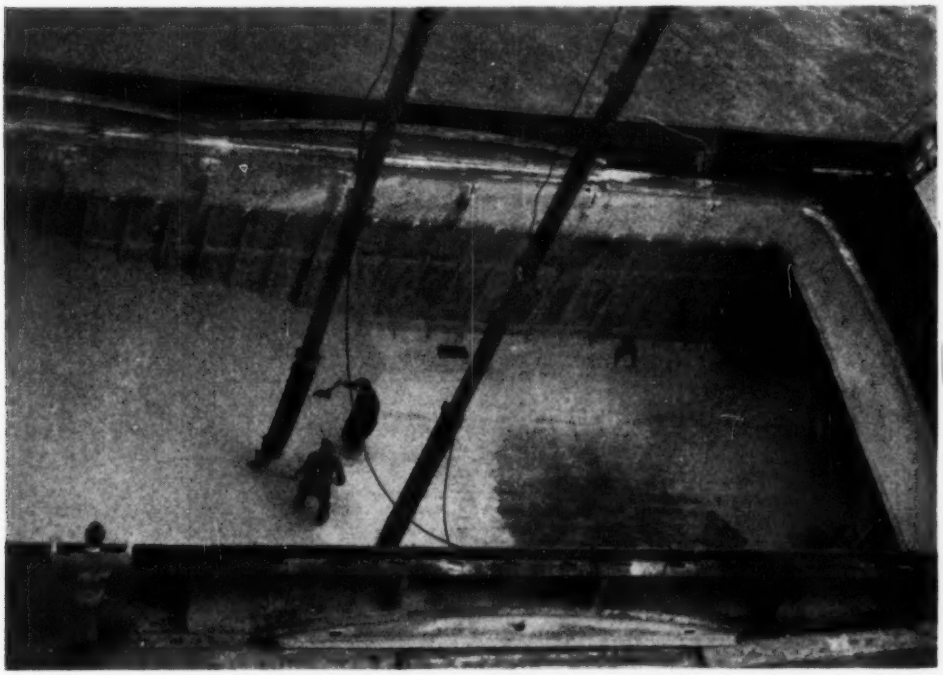

FIG. 1.—The pneumatic elevators and ship's hold.

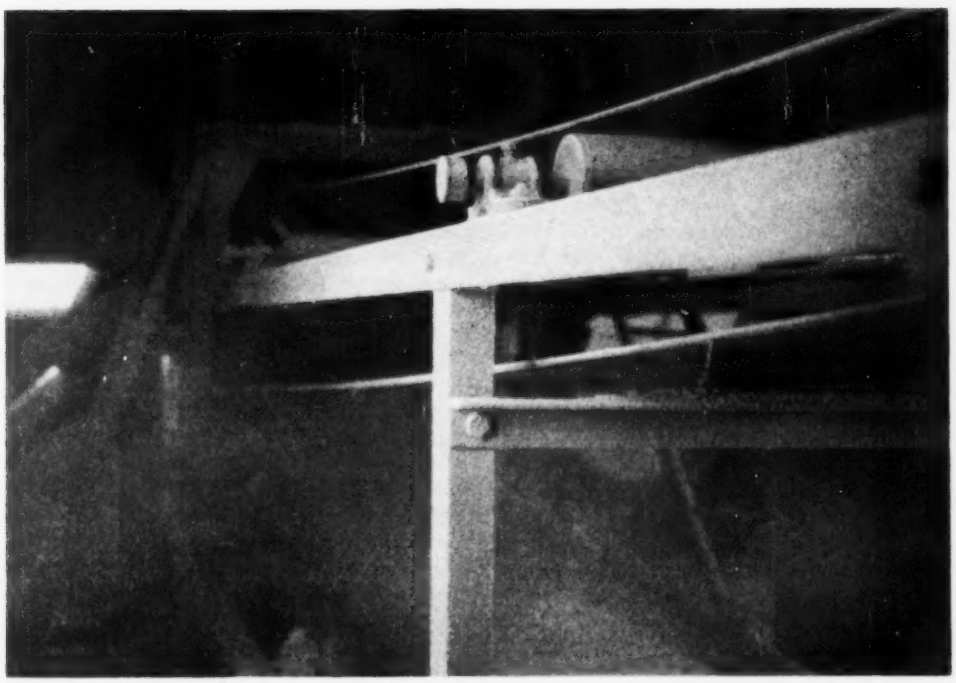

FIG. 2.—Conveyor belt in gantry.

TABLE

RELEASE OF ASPERGILLI INTO ATMOSPHERE AND CONVEYANCE OF DIFFERENT GRAINS

Experiment No.	Sites for Exposure of Plates	Dates (1959)	No. of Plates	Total Exposure Time for all Plates (mins.)	Total No. of Colonies	Total No. of Aspergilli	% Aspergilli	Catch-rate (per min.)
I	Two sites in animal provender mill under working conditions	Nov. 23	4	10·0	693	34	4·9	
		Nov. 24	4	10·0	334	16	4·8	
		Dec. 8	3	6·25	385	36	9·3	
		Dec. 14	4	10·0	341	23	6·7	
		Totals	15	36·25	1,753	109	6	3·0
II	Hatch cover during run of barley	Nov. 5	2	3·0	340	3	0·9	
		Nov. 10	3	0·5	442	3	0·7	
		Totals	5	3·5	782	6	<1	1·7
III	Silo-top during run of Manitoba No. 2 wheat	Nov. 4	2	0·66	258	15	5·8	
		Nov. 13	3	0·66	84	0	<1	
		Nov. 16	4	1·0	97	0	<1	
		Totals	9	2·33	439	15	3	6·4
IV	Silo-top (French wheat) Gantry (German wheat)	Nov. 5	4	1·0	830	19	2·3	
		Nov. 18	4	1·0	201	11	5·5	
		Totals	8	2·0	1,031	30	3	15·0
V	During run of maize Provender mill	Nov. 4	3	1·0	165	24	14·5	
	Silo-top	Nov. 10	3	1·0	210	13	6·2	
	Silo-top	Nov. 16	2	0·66	177	51	28·8	
		Totals	8	2·66	552	88	16	33·0
VI	In office room separate from provender mill; approx. 1,600 cu. ft.	Dec. 8	2	10·0	13	0		
		Dec. 14	2	20·0	98	5		
		Dec. 17	3	30·0	74	3		
		Totals	7	60·0	185	8	4	0·1
VII	Laboratory work bench	Nov. 30	4	10·0	3	0		
		Dec. 3	4	20·0	3	0		
		Dec. 8	2	30·0	7	0		
		Totals	10	60·0	13	0	<1	0·0
VIII	Urban atmosphere (public aviary)	Oct. 21	2	15·0	223	1		
		Nov. 11	2	6·0	182	2		
		Dec. 10	2	6·0	34	0		
		Totals	6	27·0	439	3	<1	0·1

From the silo, grain is transferred either to the flour mill or to the animal provender mill. The former includes the largest part of the mill, but as the machines are wholly enclosed the atmosphere is dust-free. For this reason no plates were exposed in the flour mill. All the grain used in animal feeding-stuffs (*e.g.* maize, oats, and barley) is transferred to the animal provender mill, movement within the mill being effected by conveyor belts and covered worm-screws. The atmosphere is dusty but not uncomfortable. Plates were exposed at the opened hatch-covers of the worm-screws, in order to associate spore counts with certain types of grain, and at two sites elsewhere in the animal provender mill in order to determine the spore content of the general atmosphere.

For comparison, control plates were exposed in an office room which was separate from the mill proper and where the atmosphere was apparently dust-free, in the laboratory where the cultures were handled, and in the open but protected atmosphere provided at the public aviary in the centre of the town. All the birds in the aviary were in normal health and there was no reason to suspect aspergillosis in any of them. Two birds died during the time of the experiments but autopsy and histological examination showed no evidence of fungal disease.

Results

During 1952, Richards (1956) carried out a spore survey of Great Britain, and his site for exposing plates at Southampton was the Department of Botany, University of Southampton. His data show that there was 0·56% aspergilli with a catch-rate of 0·02 per minute. These figures agree with my own obtained for the laboratory and for the urban atmosphere. In the atmosphere in the

office room it can be seen (Table) that the percentage of aspergilli is higher, although the catch-rate is still very low. The atmosphere in the animal provender mill, however, gives a catch-rate for aspergilli 30 times as great, and it is reasonable to suppose that operatives working here inhale, during working hours, 30 times the number of aspergillus spores inhaled by other workers in offices and in the open air.

In experiments II to V (Table) some attempt was made to determine whether the release of aspergilli into the atmosphere was associated with the conveyance of any particular type of grain. The number of samples was limited because grains were tested only when run for normal milling purposes. Consequently, choice of grain was not always possible, and certain grains were run only infrequently. The figures refer to threshed grain, so that although all samples included a certain amount of dust, more dust and higher figures could be expected from unthreshed grains. The hard wheats were relatively clean, while some samples of unsorted maize included particles of cob. It can be seen from experiment V that maize is associated with a higher concentration of aspergillus spores than any of the other grains tested; the catch-rate (in a moving atmosphere) is also high (33 per minute). The significance of this in relation to the importance of maize in the preparation of animal and poultry feeding stuffs remains to be determined.

At the time of the present investigation a total of 84 employees had duties to perform in the gantry, silo-top, or the animal provender mill, all of these being situations where the dust content of the atmosphere is above normal. Of these 84 employees 70 had duties confining them to the animal provender mill while 14 were employed elsewhere but nevertheless made frequent visits to the gantry, silo-top, or animal provender mill. In the first group 41 had been employed in the provender mill for over three years, while of the second group 12 had had the same mode of employment for this time.

It would have been more satisfactory to have been able to compare the incidence of pulmonary aspergillosis in two populations but the comparative rarity of the disease and the fact that it is not separately coded in the International Classification of Diseases makes an analysis of this sort impossible. For this reason information was sought concerning the claims for injury and disability arising in connexion with the work of the mill operatives.

Between December 1956 and December 1959 a total of 31 employees of the firm sought compensation for disease or injury arising out of their work; none of these was claiming for chest disease. Moreover, during the eight-year period December 1951 to 1959 when the present machinery in the mill has been in use without major modification, no single case of pulmonary aspergillosis has been reported. The disease, in fact, is unknown at the mill. It seems, therefore, that millers show no special liability to mycotic pulmonary disease even though they may be exposed for a long time to an atmosphere with a high spore content.

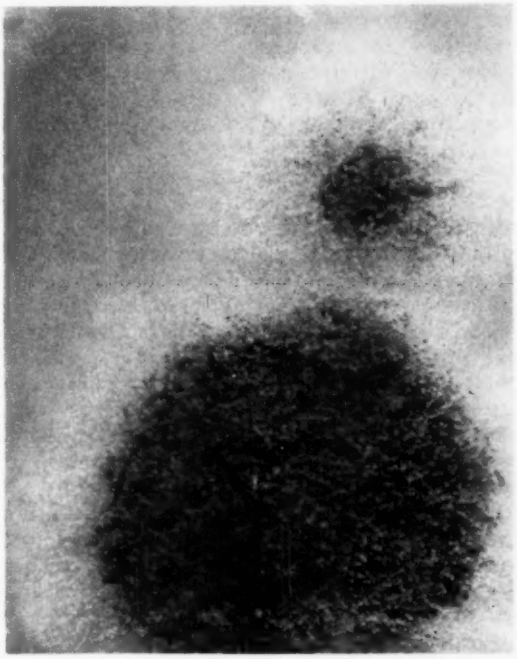

FIG. 3.—*A. clavatus*, × 2½. Sabouraud agar.

The actual numbers of employees just quoted refer only to the three-year period between December 1956 and December 1959 because it was felt that a more accurate record of the type of employment would be gained by restricting the time covered to this limit. It may be argued that the three-year period is too short a one in which to expect any claim for pulmonary aspergillosis to be made but the author knows of no evidence to suggest that a more prolonged exposure is necessary to cause infection, although duration of exposure will naturally influence the development of the disease by prolonging the daily risk of inhaling an infective atmosphere.

During the experiments aspergilli belonging to several groups and species were isolated. These included *A. amstelodami*, *A. repens*, *A. ruber*, *A. clavatus* (Fig. 3), *A. flavus*, *A. fumigatus*, and *A. niger*. These and the *A. glaucus* group have at one time or another been incriminated as human

pathogens, so that the experiments provide some evidence of the significance of spore content of the atmosphere in the causation of human pulmonary aspergillosis. It seems that this disease does not result from inhalation of an atmosphere associated with a catch-rate for aspergilli of 3·0 per minute or less. It may have been for this reason that Dunner *et al.* (1958) failed to associate fungi of any genus with 30 out of 31 grain workers who had had chest symptoms. In the single case in which fungi were demonstrated in the lungs at autopsy identification was not complete, and the fungus was not an aspergillus.

The experiments also show that so far as some mill operatives are concerned, there may be temporary exposure to a potentially more infective atmosphere. For example, experiment III (hard wheats) shows a catch-rate of 6·4 per minute, experiment IV (soft wheats) 15·0 per minute, and experiment V (maize) 33·0 per minute; these high figures are partly the result of air movement near the conveyor belt where the plates were exposed, but they are nevertheless worthy of consideration. No data have been obtained for unthreshed grain and it would be of interest to obtain figures for the atmospheric spore content under threshing and stable conditions (Tscherniak, 1928).

I am pleased to acknowledge the assistance of Dr. J. Walker of the Mycological Reference Laboratory for help in identifying the aspergilli; and the courtesy of Messrs. Joseph Rank Ltd., Southampton, F. T. Everard and Sons Ltd., and the British Transport Commission.

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CHRISTMAS DISEASE AND COAL-MINING

TRAUMA AND EXPOSURE TO NITROGLYCERINE AS OCCUPATIONAL HAZARDS

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The main features of Christmas disease, a hereditary disorder of blood coagulation, are outlined, and a family of coal-miners who suffer from this disorder is described.

The affected male members of two generations have spent their working lives underground. Three of the eight affected miners were temporarily severely disabled by episodes associated with their bleeding diathesis, and one died in 1894 from haemorrhage following an injury.

A mild degree of Christmas disease caused an increased occupational morbidity in some members of this family, but did not shorten their overall working life-span. Twelve further cases of Christmas disease are briefly described.

One affected man had an episode of cerebral haemorrhage, possibly associated with the physiological effects of contact with nitroglycerine. A review of the literature suggests that nitroglycerine may have a significant aetiological action in the development of cerebral haemorrhage in men with a defective haemostatic mechanism.

Finally, it is suggested that an analogous situation may exist in patients under anticoagulant treatment, who use nitrates or other vasodilator drugs therapeutically.

Christmas disease is one of the hereditary disorders of blood coagulation which is transmitted as a sex-linked recessive trait by females, the clinical manifestations appearing only in the male. It was separated from the other haemophilioid diseases in 1952, simultaneously in England by Biggs, Douglas, Macfarlane, Dacie, Pitney, Merskey, and O'Brien (1952) and in the United States by Aggeler, White, Glendening, Page, Leak, and Bates (1952).

Christmas factor (Factor IX, plasma thromboplastin component) is necessary for thromboplastin generation in the first stage of coagulation and is deficient in this disorder. The clinical and genetic features are indistinguishable from the more common antihaemophiliac globulin (AHG or Factor VIII) deficiency (Biggs and Macfarlane, 1957).

Didisheim and Lewis (1958) reviewed all published reports of patients with inherited disorders of coagulation and concluded that the average incidence of Christmas disease was 16% of all patients. Of 106 patients with these disorders who attend the Royal Prince Alfred Hospital, Sydney, New South Wales, 17 (16·0%) have Christmas disease. Of the remainder, 96% have classical haemophilia. A summary of 12 cases of Christmas disease who are of employable age, and who are attending R.P.A. Hospital, is given in the Table.

Patients with Christmas disease, like those with classical haemophilia, show haemorrhagic manifestations of varying degrees of severity, roughly parallel to the factor deficiency in the blood, which may be measured by the activity of the patient's plasma or serum in artificial clotting systems and expressed as a percentage of the normal level.

Thus a severe case of Christmas disease with a Christmas factor level of 0-1% of normal will have extensive subcutaneous and intramuscular effusions of blood, and, from an early age, recurrent haemarthroses, all of which may arise from such minimal trauma as to appear "spontaneous". Gastrointestinal bleeding is common, and haemorrhage in other sites may, by compression or obstruction of vital structures, cause a variety of syndromes.

Mild cases have a Christmas factor level of 5 to 50% and, generally speaking, only manifest signs of deficient haemostasis if they are exposed to severe trauma, teeth extraction, or surgical procedures. Haemarthroses and haematomata from

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minimal trauma are rare in this group. There are a few patients with levels of Christmas factor between these two groups, and who are moderately affected clinically. The family to be discussed belongs to the mildly affected group.

Until fairly recently, little has been written about the employment of men suffering from the haemophilioid disorders. This is probably due to previous poor prognosis. Andreassen (1942) gave a life expectancy of about 16 years and authors tended to emphasize the more severely affected patients, who without the benefit of the improved management of the last decade, formed a largely crippled group with poor employment potential (Favre-Gilly, 1957).

However, Quick (1957) stresses that the outlook is far more encouraging now as most haemophiliacs are gainfully employed; some are labourers, exposed to trauma, who work steadily for surprisingly long periods.

Family of Coal-miners with Christmas Disease

There are 13 affected males in five generations of this family (Fig. 1). Three of the affected members in generation III emigrated from Staffordshire in 1923 to the coalfields near Wollongong, N.S.W. In generations II and III all males of employable age worked as coal-miners, but only those with Christmas disease are considered here.

Generation II.—The four affected members in this generation are all dead; their manifestations were described by their relatives. They are said to have had numerous traumatic episodes with persistent haemorrhage or haematomata.

Three lived to the age of 60 or over but the fourth, when aged 45 (in 1894), suffered a compound fracture of the leg in an underground accident and is said to have "bled to death" shortly afterwards.

Generation III

III—1, a boy, 10 years of age, who died from exsanguination due to four days of uncontrollable bleeding from a lacerated hand (not investigated, the case was detailed by his relatives).

III—2, a man, 72 years of age, with a tendency, noticed at an early age, to bleed excessively after trauma and tooth extraction. For over 30 years he was employed underground, working at the coal-face. Apart from several lacerations and bruises, none of which proved serious enough for admission to hospital, he suffered two major bleeding episodes which required several blood transfusions and treatment in hospital for several weeks. These episodes were an extensive haematoma of the thigh which burst through the skin following a fall of coal onto his leg, and on another occasion, an episode of severe haematuria after being struck in the abdomen by an underground truck. This patient was interviewed personally.

III—3. He was 65 years of age. He remained in Staffordshire and despite frequent haemorrhage into the thigh and calf, he was a skilled soccer player. Although he spent most of his working life at the coal-face he suffered nothing more serious than a few episodes of prolonged bleeding after lacerations, insufficiently severe to require hospital treatment (not interviewed; case described by his brothers).

III—4. He died at the age of 60 after an episode considered by his local doctor to be due to cerebral thrombosis. He was also thought to have suffered from ischaemic heart disease. He spent most of his working life at the coal-face and was in hospital several times for bleeding from lacerations; on two occasions he was given blood transfusion.

This case was described by his attending physician, who was certain that he had a haemorrhagic disorder. The diagnoses of cerebral haemorrhage and ischaemic heart disease were based on clinical observations. No haematological investigation or post-mortem examination was undertaken.

III—5. This patient, 51 years of age, was studied personally in detail. He had his first haemorrhagic manifestation at the age of 4, when he bled for over a week from a lacerated forehead. After numerous traumatic haemorrhages and several troublesome bouts of epistaxis, he had his first blood transfusion at the age of 30 following tooth extraction. In the past 18 months he has had two episodes of gastrointestinal bleeding. In

TABLE

PATIENTS OF EMPLOYABLE AGE WHO ARE ATTENDING ROYAL PRINCE ALFRED HOSPITAL ON ACCOUNT OF CHRISTMAS DISEASE

Case No.	Age (years)	Degree of Severity of Christmas Disease	Occupation	Main Permanent Physical Disability
*1	52	Severe	Housekeeper	Severe arthritis of both knees
2	19	Severe	Watchmaker	Moderate arthritis of both knees
3	17	Severe	Hairdresser	Mild arthritis of both knees
4	19	Moderate	Clerk	Moderate arthritis of right knee
5	17	Moderate	Bank clerk	Moderate arthritis of both knees
6	77	Moderate	Hairdresser (retired)	Severe arthritis of both knees
7	61	Mild	Gas fitter	Nil
8	58	Mild	Sign writer	Nil
9	52	Mild	Lorry driver	Nil
10	51	Mild	Printing press operator	Nil
11	38	Mild	Town clerk	Nil
12	24	Mild	School teacher	Nil

* Case 1 was formerly a pastrycook but had to change his occupation on account of disability.

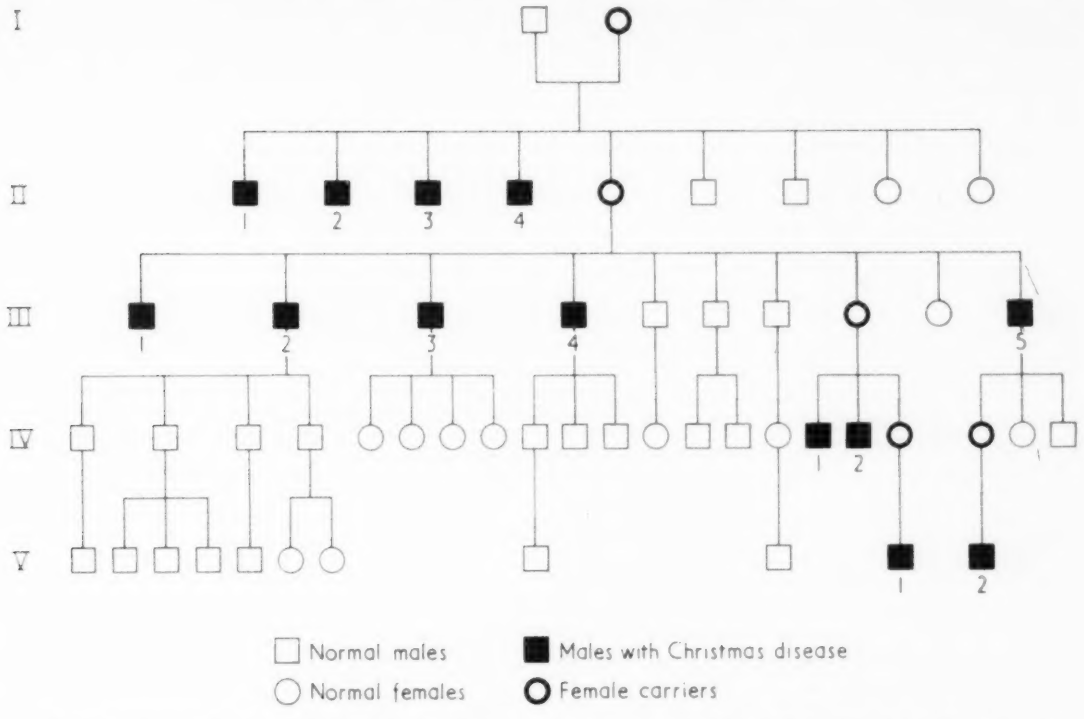

FIG. 1.—Genealogical tree of the family affected by Christmas disease. NOTE.—Females without offspring may be potential carriers.

1959 coagulation studies demonstrated a haemostatic defect and the thromboplastin generation test (Biggs and Douglas, 1953) showed his defect to be consistent with a mild deficiency of Christmas factor. He started work in the mine at the age of 14 on various underground jobs. For the past 20 years he has been employed as deputy under-manager, and his responsibilities have included the handling and detonation of charges containing nitroglycerine. In his 36 years of employment in a coal-mine he has had four episodes of disability associated with his work. The first two were the result of severe bruising; on one occasion arising from a fall of coal from the roof, and the other resulting from a fall into a coal skip. He was off work for only a few days with each of these episodes. On the third episode he cut his hand severely while inserting a metal sprag into a skip wheel and this led to persistent bleeding over a period of six weeks, with repeated suturing of the wound and several blood transfusions. The last episode occurred in August, 1959. One Monday afternoon he developed his customary headache after handling a moist charge containing nitroglycerine. On returning home he told his wife about the severity of his generalized throbbing headache and went to bed. The following morning he mentioned that he still had his headache, which was most unusual as a short sleep had invariably relieved the numerous headaches he had had previously following contact with nitroglycerine. During work that day he became confused and disorientated, and was put to bed. He then complained of a stiff neck and pain in his back and down the back of his legs, and this continued for three days. Lumbar puncture revealed blood-stained cerebrospinal fluid; the pressure was not recorded. He was then admitted to Royal Prince Alfred Hospital. On admission, he was a man of good physique who was confused and mildly hallucinated. He complained of a severe frontal headache and a stiff neck. He was afebrile. Examination revealed marked neck rigidity, stiffness of the back muscles and a positive Kernig's sign. The other significant neurological findings were diminished power and reflexes in the left arm and a right grasp reflex. There was no external sign of recent head injury. His blood pressure was 160/100 mm.Hg on admission and his Hb 12·6 g./100 ml. Christmas factor level was over 5% of normal. No other abnormalities could be found in any other body system.

A provisional diagnosis of subarachnoid haemorrhage was made and the possibility of a subdural haematoma was also considered. Radiograph of the skull showed no sign of fracture nor of pineal shift. An electroencephalogram showed a grossly abnormal record with right fronto-temporal slow activity considered more suggestive of intracerebral bleeding than of a subdural collection.

Fresh human plasma was given by continuous intravenous infusion, one unit (250 ml.) every four hours for

two days and then one unit every six hours for a further eight days, to raise his level of Christmas factor sufficiently to lessen the chance of further bleeding.

Twenty-four hours after commencing plasma infusions his condition improved and six days later he was perfectly rational and had lost all signs of neurological disturbance. He was discharged from hospital five weeks after admission with no evidence of physical or mental abnormality, but the electroencephalogram still showed a persistent focus in the right fronto-parietal region. Seven months after his initial illness he was still in excellent health and his electroencephalogram was normal.

Generation IV.—The two affected males have been investigated at another hospital and classified as having Christmas disease.

Generation V.—The two affected males were investigated and treated at Royal Prince Alfred Hospital for haemorrhage after trauma. Christmas factor level was over 5% of normal in each case. A summary of 12 further cases of Christmas disease is given in the Table.

It is difficult to classify the disability adequately in these cases. Some are handicapped by recurrent bleeding from peptic ulcer or haemorrhoids, or by haemorrhage into the joints and after teeth extraction or operations. Functionally, haemophiliac arthritis of the knees is the sole permanent disability of these people and pain, deformity, or restricted movement in these joints is what troubles them in their occupation. On a functional classification, severe arthritis indicates that the patient is handicapped to the extent of needing assistance (by surgical appliance, crutches, or walking sticks) in carrying out his everyday occupation. By moderate arthritis is meant that the patient can cope with everyday activity without mechanical assistance, but still retains a significant disability, for example in climbing stairs or running. In mild arthritis there is no significant handicap.

All 12 patients are gainfully employed; the retired hairdresser worked until he was nearly 70. Only one patient (Case 1) had to leave his occupation of choice on account of disability and most are in very suitable non-traumatic occupations.

Discussion

Christmas Disease and Coal-mining.—It seems reasonable to assume that the branches of coal-mining in which this family work constitute a source of potential trauma, the effects of which are rendered more disabling or life endangering by the associated haemostatic defect.

Of the 13 males of generations II and III engaged in coal-mining (III—1 died at the age of 10) eight are considered to have Christmas disease and five are normal. There were two occupational deaths in these men; the one, mentioned above, from haemorrhage following a leg injury in 1894, and the other, more recently, when a normal male was killed in a roof fall. Of the remaining seven with Christmas disease, three appear to have suffered severe temporary disability associated with their occupation and all seven, except the youngest miner (age 51), have reached the seventh decade.

In this family insufficient data were collected to show whether affected males had more occupational morbidity than their normal brothers. However, a mild degree of Christmas disease did not appear to interfere with the long-term employment of those affected. Trauma is the main hazard for affected males, and it is suggested below that nitroglycerine is a possible aetiological factor in the development of cerebral haemorrhage.

Lacerations, particularly of the extremities, are frequent. With modern methods of securing haemostasis by local haemostatic agents, suturing, and factor replacement therapy, where necessary, together with the control of infection, haemorrhage from most wounds should not prove too difficult to control (Sawers, 1958).

Nitroglycerine.—It is possible that the physiological effects of nitroglycerine may have had some aetiological significance in the cerebral haemorrhage of patient III—5. As far as is known, he was the only affected member of his family to use this agent.

The presence of cerebral aneurysm cannot be excluded but this appears unlikely in view of the clinical course, the return of the electroencephalogram to normal in seven months and the high mortality in proven cases. McKissock and Paine (1959) report death in 57% of 355 cases of cerebral aneurysm proven by angiography at operation, or at autopsy. With a superimposed coagulation defect the prognosis in ruptured cerebral aneurysm must be very poor.

Carotid angiography was not undertaken in this patient (III—5), because, even in people with apparently normal haemostasis, a cervical haematoma has caused respiratory obstruction serious enough to warrant tracheotomy (Sugar, Holden, and Powell, 1949).

The patient can recall the events leading to his illness and is certain he sustained no head injury of any nature during the weeks before the onset of symptoms, and this is supported by his wife and workmates and by the negative findings of physical examination.

The patient was not hypertensive, his blood pressure was 130/90 mm. Hg on several occasions during his convalescence, and there was no clinical or electrocardiographic evidence to suggest widespread atherosclerosis affecting the cerebral vessels.

The association of his cerebral haemorrhage with

the severe headache of nitroglycerine therefore seems worthy of further discussion.

The explosive mixture the patient used before his illness contained between 16 : 1 and 14 : 1 parts by weight of nitroglycerine and nitroglycol.

Nitroglycerine (glyceryl trinitrate) is well known as a cause of severe headache and was originally described by Laws (1910) and Evans (1912). The basic action of glyceryl trinitrate is to relax smooth muscle throughout the body, particularly in the finer blood vessels (Goodman and Gilman, 1955a).

Bovet and Gatti (1955) concluded that the cerebral vessels were probably more sensitive to glyceryl trinitrate than the vessels of other regions. Goodman and Gilman (1955b) considered the headache was due to a rise in intracranial pressure caused by dilatation of meningeal and intracerebral vessels. However, Schwartz (1946) concluded that the headache caused by contact with nitroglycerine was closely analogous to that following histamine injection, and Schumacher and Wolff (1941), who studied the histamine headache, found that there was not only a dilatation of the cerebral vessels, but that when the lowered cerebrospinal fluid pressure associated with a reduction in systemic blood pressure was raised, either by vasopressor drugs or by direct introduction of saline into the subarachnoid space, the headache was relieved.

On this evidence the two main components of headache caused by these vasodilator drugs appear to be dilatation of cerebral vessels and a fall in cerebrospinal fluid pressure.

It has been shown by Wolff (1955) that in bouts of migraine there may be conspicuous damage to the vascular walls of dilated temporal arteries or their branches. This is manifested by haematomata adjacent to these affected arteries appearing 10 to 60 hours after severe migrainous headaches.

The profound intracranial volume changes caused by the physiological effects of vasodilator drugs might reduce the support for the dilated intracranial vessels sufficiently to damage their walls. When the normal haemostatic mechanism is defective as in Christmas disease the likelihood of significant haemorrhage is greatly increased and a minute vascular leak that would be arrested before it assumed clinical significance in a normal person, could cause serious effects.

In several studies on workers who died suddenly after exposure to nitroglycerine, there was no mention of cerebral haemorrhage found at autopsy, nor was the possibility mentioned. In the absence of any significant pathological findings at autopsy sudden death was ascribed to circulatory collapse due to the effect of nitroglycerine on the cardiovascular system (Symanski, 1952; Forssman, Masreliez, Johansson, Sundell, Wilander, and Boström, 1958; Maccherini and Camarri, 1959).

Although it cannot be said that nitroglycerine is of any aetiological significance in causing cerebral haemorrhage in normal people, nevertheless, for the reasons outlined above, it may endanger those whose haemostatic mechanism is defective. Workers with any form of coagulation disorder should not have contact with this agent.

The Use of Vasodilator Drugs During Anticoagulant Therapy.—There is the analogous situation of patients with thrombo-embolic disease, particularly those with ischaemic heart disease, on anticoagulant therapy, who use nitrates or other vasodilators to relieve angina pectoris.

The commonly used anticoagulant drugs are either coumarin or indandione derivatives which cause a deficiency of several coagulation factors, including Christmas factor (Douglas, 1955). Discussing patients on anticoagulant therapy, Peyman (1958) concluded that although the most obvious effect of these drugs was an interference with normal blood coagulation other factors such as capillary damage might be as important, if not more so, in the development of haemorrhage. This observation supports the earlier report of Spaet (1952) who considered a combination of coagulation and vascular defects necessary before a haemorrhagic state was established.

In reports on cerebral haemorrhage during anticoagulant therapy no information could be found to incriminate vasodilators as an associated cause (see, for example, Russek and Zohman, 1953).

Although there has been no reported relationship between these two groups of drugs in the production of cerebral haemorrhage, their possibly significant association has not apparently been considered.

I wish to thank Professor C. R. B. Blackburn, Department of Medicine, Sydney University, for permission to describe the affected members of this family who have been in hospital under his care, and Dr. H. Kronenberg, Haematologist, Royal Prince Alfred Hospital, who performed the coagulation studies.

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METHYL BROMIDE POISONING

BY

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Seven cases of methyl bromide poisoning which occurred amongst workers engaged on a fumigation project are described. The methods adopted for investigation of the environmental situation are discussed and the measurement of blood bromide levels on random samples of workers is suggested as an index of the effectiveness of equipment and working methods.

Methyl bromide is a highly volatile liquid which disperses rapidly and readily. As a fumigant it ranks amongst the most efficient because of its extremely effective penetrating power and absence of fire or explosion hazard. It is, unfortunately, highly toxic and poisoning occurs readily in circumstances of careless or inadvertent exposure.

Before 1940, only 42 cases of methyl bromide poisoning had been reported, mostly in Germany. Twelve of these had been fatal. With the advent of the second World War and the use of methyl bromide as a fire extinguisher in ships, a further 26 cases were reported in the Royal Navy with eight fatalities (Clarke, Roworth, and Holling, 1945).

Mazel, Bourret, and Roche (1948) reported an astonishing case which occurred in France where a whole family of five were poisoned, the three children being fatally affected. In this case, the family had continued to occupy part of a house while the rest was being treated.

Present Investigation

A large housing scheme, which involved the construction of some 2,700 houses, was undertaken in Queensland some years ago. Much of the timber (a European soft-wood, prone to infestation by the European house-borer, *Hylotrunes bajulus*) was precut and imported from various European countries.

By 1956, it was obvious that the borer was present in the timber of these houses and it was decided to undertake mass fumigation with methyl bromide.

Method of Fumigation.—Several adjoining houses were evacuated and completely covered by heavy-duty polythene sheeting. Methyl bromide was then run in from cylinders to a concentration of 4 lb./1,000 ft.^{3}. The sheeting was left untouched for 24 hours. At the end of this time the sheets were lifted and all doors and windows were opened. Tenants were allowed to return after the houses had been aired for not less than three days, and negative readings for halides had been obtained at all points with a halide detector.

About 40 men were engaged in the actual fumigation procedures and a total of between eight and 10 houses were completed daily, depending on weather conditions. Altogether, 2,643 houses were fumigated in a period of 16 months, extending from February, 1958 to May, 1959.

Safety Precautions.—These stated that respirators comprising regulation Army type facepieces (as issued in the period 1941 to 1942) with gas canisters effective against methyl bromide were to be used at all times when exposed to gas. The equipment was inspected by the Department of Industrial Medicine and scientists of the Government Chemical Laboratory; canisters stated to be effective against methyl bromide were inspected and tested before fumigation began. These canisters absorbed high concentrations of chloroform vapour (5 lb./1,000 ft.^{3}) for 34 minutes, and were also found to be capable of absorbing methyl bromide at a concentration of 3·5 lb./1,000 ft.^{3} for 22 minutes.

A circular letter describing the symptoms of exposure was provided and the usual exhortations for care by the operators were made. Exposure to concentrations of the gas was to be cut to a minimum by proper organization, and only to be allowed during the necessary lifting of the sheeting and the opening of doors and windows.

All the cases to be described occurred amongst men exposed to the greatest concentrations of gas, that is, those men who cleared the houses for

TABLE 1
SUMMARY OF CASES

Case No.	Date of Onset	Period in Hospital	Result	Blood Bromide on Admission (mg./100 ml.)	Electroencephalogram
1	30.4.58	10 weeks	Gross disability	40 (Gold chloride)	Two months after admission; alpha rhythm 9 c.p.s. with faster activity. Occasional symmetrical 5-6 c.p.s. activity from all regions
2	29.5.58	10 days	Epilepsy	25 (Gold chloride)	Five months after admission; no abnormality
3	2.6.58	Not admitted	Recovery complete	2·4 (Conway)	—
4	24.7.58	6 weeks	Moderate disability	13·5 (Conway)	Five months after admission; no abnormality
5	25.7.58	6 days	Recovery complete	7·2 (Conway)	—
6	25.7.58	6 days	Slight residual ataxia	17·6 (Conway)	—
7	26.7.58	6 days	Recovery complete	9·6 (Conway)	—

ventilation after fumigation had progressed for the requisite time.

On April 30, 1958, the first case occurred and was admitted to hospital, with serious methyl bromide poisoning. After this incident, a tightening up of all procedures was planned and an army-type discipline was instituted under a safety officer. However, further cases occurred on May 29, July 1, and July 25.

This outbreak of cases of methyl bromide poisoning was investigated by the Division of Industrial Medicine. An alarming feature was the fact that three of the four cases which occurred on July 25 showed severe erythema of the face under the mask, indicating the presence of free methyl bromide in the inspired air.

The efficiency of the canisters was suspected and tests on those supplied revealed that none of them protected against methyl bromide for more than 30 seconds.

The cases are summarized in Table 1.

Case Histories

Case 1.—While at work he started to vomit and noticed he was short-winded. On the way home, two hours later, he noticed twitching of the muscles of the right leg.

On arrival at hospital he evidenced an epilepsia partialis continuans of the right foot, and right ankle clonus was present; plantars were flexor. While being examined he had two major fits and passed into status epilepticus.

For the next seven days he was unconscious, responding to painful stimuli; peripheral stimuli produced epilepsia partialis continuans of the limbs. His generalized convulsions ceased on the third day, after large doses of sod. phenobarbitone intramuscularly and myanesin intravenously.

On discharge from hospital, 10 weeks after admission, he was still grossly ataxic and was experiencing recurrent Jacksonian motor attacks of the right leg, and local myoclonia of the right arm. His signs have remained unchanged until the present time (May, 1960).

Case 2.—Fourteen hours after completing a fumigation he found he could not keep his balance and was admitted to hospital.

Three epileptiform seizures occurred in the next three days. There was gross intention tremor of the right hand and ataxic gait. His signs cleared up over the following six months, though he has subsequently had several grand mal attacks, and, in addition, episodes which are hysterical in nature. No previous history of fits of any kind could be obtained.

Case 3.—He complained of dizziness, nausea, and red eyes but recovered rapidly. The conjunctival irritation was regarded as evidence of minimal exposure.

Case 4.—He inhaled methyl bromide two hours before admission to hospital. On admission he was drowsy and half an hour later he had a generalized fit. The following day he had generalized convulsions when disturbed. He was unconscious for three days. On regaining consciousness he had visual and auditory hallucinations lasting 24 hours. He manifested a gross tremor in the finger-nose test and ataxic heel-knee test, an increased tone in the limbs, increased deep reflexes, and extensor plantar reflexes.

When examined 10 months later, his left pupil reacted sluggishly to light. There was an intention tremor of the left hand; he walked on a wide base; heel-toe walking was unsteady. There were increased deep reflexes in the arms and cogwheel rigidity at the right wrist. He was experiencing myoclonic jerks in the legs at night. He stated that on one occasion while walking along the road, a pipe was dropped near him and he was suddenly and spontaneously thrown to the ground.

Case 5.—While fumigating he noticed dizziness. Next morning, on getting out of bed, he suffered violent shaking, commencing in the left foot, which spread up his leg and was of such force as to throw him backwards.

On examination, he had nystagmus and any movement of the left foot produced an epilepsia partialis continuans which at intervals progressed to a Jacksonian motor attack.

Case 6.—In this case also there was a latent period of 12 to 18 hours after fumigation before unsteadiness in walking and incoordination of the left arm were noticed.

Six months after admission he was slightly unsteady on heel-toe walking.

Two days after admission to hospital he developed a Jacksonian motor attack in his left leg, which spread to involve the left arm.

Case 7.—This case had a latent period of 12 to 14 hours after fumigating. He then complained of dizziness and was unsteady on his feet. There was incoordination of the left arm and ataxia in heel-toe walking.

The Tests

When four cases occurred in one day (24/25 July, 1958) it was realized that the fault could not lie in carelessness unless there had been a complete breakdown in discipline. As it was known that this was not the case, and the men were all cognizant of the severity of poisoning as a result of Case 1, the canisters were suspected and a test was made by using a fully gassed house as source of supply of methyl bromide at 4 lb./1,000 ft.^{3}.

The canisters were connected to a Willson pump adjusted to a flow-rate of 15 litres per minute, though some tests were run at 20-22 litres. The inlet valve was either connected to a pipe passing under the sheet, or the canister itself placed within the canopy. The other end of the canister was led via the pump to a 4-gallon drum with a relatively narrow opening. The tubing was let down to the bottom of the drum and the air supply nozzle of a halide lamp was let down to just within the opening.

Breakdown of a canister was accepted on the first showing of a light green halo on the halide lamp.

Tests were carried out on the same apparatus by human aspiration in lieu of the pump, utilizing the same apparatus but substituting an Erlenmeyer flask for the drum. It was reasoned that, in view of the rapid breakdown, the smaller the volume inhaled, the better it would be for the volunteer.

All canisters were found to break down from 30 seconds to one minute, and to allow 200-500 parts per million to pass after this time. The canisters of all seven cases (including Case 1 whose canister had been retained) showed no protection whatever.

It was concluded, therefore, that all the affected men had been breathing methyl bromide vapour in concentrations up to 4 lb./1,000 ft.^{3} for short periods during fumigation operations, and this was sufficient to cause severe poisoning in two cases.

The fact that the faces of three men were burnt within the area of face covered by the respirators indicates that the gas must have been coming through the canisters. There did not seem to be any reason to suspect that masks were ill-fitting or that gas could have passed under the edges of the face-pieces.

Method of Estimating Bromide in Body Fluids

Gold Chloride Method is an easy and convenient method for estimating intoxication with metallic bromides or ammonium bromides. It is suitable only for the higher levels from 25 to 200 mg./100 ml.

Fluorescein Test is inaccurate and merely indicates levels above or below 5 mg./100 ml.

Conway's Micro-diffusion Method (Conway, 1950) is the only method suitable for the estimation of blood bromides in methyl bromide poisoning. The tolerances possible with colorimetric methods such as the gold chloride method are not accurate enough for levels below 10 mg./100 ml. Symptoms of poisoning are possible at levels as low as 2·8 mg./100 ml., and severe symptoms at as little as 12 mg./100 ml. The supervision of workers engaged in large scale operations should include blood bromide surveys of random groups at frequent intervals. Blood bromide levels enable an estimate to be made of the efficiency of safety precautions and of safety equipment. The method is accurate enough to define exposure fairly exactly, particularly so when a man presents with symptoms which are not specific. A negative finding will exclude methyl bromide as the cause.

It is, therefore, emphasized that for the purposes of supervision, where levels of blood bromide below 5 mg./100 ml. are to be expected, the micro-diffusion method of Conway is mandatory.

The results of bromide estimations are given in Table 2.

From the experience gained in the situation described it is clear that the presence of bromide in the blood of any worker should indicate the need for a reinspection of equipment, examination of precautions, and a search for the responsible flaw.

In this case, the certainty that strict precautions were being followed led to an examination of the equipment, with the discovery that the canisters offered no protection from the gas. As a result, the total consignment was condemned and a reliable and well-known make substituted. Preliminary tests on these canisters showed full protection for more than an hour at a concentration of 4 lb./1,000 ft.^{3} After these canisters were used, no man showed the slightest trace of bromide in the blood after working continuously in exposed situations.

Discussion

The mechanism of action of methyl bromide was discussed by Clarke *et al.* (1945) who showed that there is no apparent relationship between methanol and sodium bromide poisoning and methyl bromide poisoning. In summary, amblyopia is never found

TABLE 2
BROMIDE ESTIMATIONS

Case No.	Date	Method	Blood Bromide (mg./100 ml.)	Cerebrospinal Fluid Bromide (mg./100 ml.)	Urine Bromide (mg./ 100 ml.)
1	30. 4.58	Gold chloride	40	—	—
	1. 5.58	Gold chloride	40	—	—
	1. 5.58	Gold chloride	—	15	—
	2. 5.58	Gold chloride	40	—	—
	5. 5.58	Gold chloride	25	—	—
	6. 6.58	Gold chloride	nil	—	—
2	29. 5.58	Gold chloride	25·0	—	—
	2. 6.58	Conway	12·0	4·5	—
	6. 6.58	Conway	4·8	—	—
3	19. 6.58	Conway	2·4	—	—
	1. 7.58	Conway	2·4	—	—
	31. 7.58	Conway	1·5	—	—
	10.10.58	Conway	nil	—	—
4	25. 7.58	Conway	13·5	—	—
	28. 7.58	Conway	6·0	8·0	1·6
	6. 8.58	Conway	4·8	—	—
	5. 9.58	Conway	1·5	—	—
5	25. 7.58	Conway	7·2	—	—
	28. 7.58	Conway	7·2	—	7·2
	8. 8.58	Conway	1·0	—	—
	12. 9.58	Conway	Undetectable	—	—
6	26. 7.58	Conway	17·6	—	—
	28. 7.58	Conway	12·0	—	13·6
	6. 8.58	Conway	8·4	—	—
7	26. 7.58	Conway	9·6	—	—
	28. 7.58	Conway	6·4	—	3·0
	8. 8.58	Conway	1·5	—	—
	31.10.58	Conway	nil	—	—

in methyl bromide poisoning, nor do fits occur in methanol poisoning. Clarke *et al.* (1945) concluded that some unknown decomposition product is the responsible factor, but in our opinion, there is no need to postulate any more complicated chemical action than a direct attachment to intracellular protein moieties.

The medicinal or water soluble bromides (NaBr, KBr, NH_4Br) do not cause toxic symptoms until a blood level of at least 50 mg./100 ml. is reached. In a general way, the symptoms overlap those of methyl bromide poisoning, but complete recovery is the rule in therapeutic overdosage with bromides.

The presumption is that methyl bromide attaches itself to protein molecules as do the heavy metals, and probably attaches itself to the sulphydryl groups. Its affinity appears to be for the conjugated intracellular proteins which comprise the complex enzyme systems.

The general disturbance of the central nervous system in acute poisoning may be explained on this basis of interference with essential intracellular metabolic processes. The gradation of severity with exposure, and the known possibility of recovery from minimal absorption, may be explained as recovery of partially damaged cells gradually returns to normal levels. Where, however, destruction of any cellular system has been complete, residual damage is permanent.

Methyl bromide has a fairly specific effect on cortical, cerebellar, and basal ganglion structures, and is probably first absorbed in the extracellular fluid and slowly diffuses into the cells and interferes with their metabolism, affecting the enzyme system which controls intracellular oxidative reactions. In low concentrations, it is irritative and in higher concentrations paralytic; its action thus depends on the concentration of the conjugated methyl bromide complex in the cells.

On this basis, it was decided to use B.A.L. in all cases admitted to hospital, and though Case 1 only had B.A.L. late in the recovery phase, all subsequent cases were treated with B.A.L. as routine. All the seven cases in this series survived.

In all cases there was a latent period between exposure and the onset of neurological symptoms and signs. In the milder cases these took the form of giddiness, epileptic attacks, which in some cases were continuous, and ataxia. In the more severe cases there was unconsciousness, with pyramidal and extra-pyramidal signs. In the severe cases the neurological signs persisted (Cases 1, 2, 4, and 6).

The portions of the central nervous system which were chiefly affected were the cerebral cortex, the basal ganglia (pallidum), the cerebellum, and probably the red nucleus (Dechaume, Bourrat, Schott, and Buffard, 1948).

The time of onset of neurological symptoms varied from two to four hours after exposure. A sweet odour of the breath was noticeable for some days after admission to hospital. Cases 1 and 4 showed a cyanotic tinge in the skin which was present before the onset of any evidence of pulmonary oedema. The early exhibition of B.A.L. in such cases possibly

TABLE 3

BLOOD BROMIDES: RANDOM SAMPLES ON WORKERS USING OLD TYPE CANISTERS UP TO AUGUST 29, 1958

Date	Blood Bromide (mg./100 ml.) (Conway)	Remarks
3.6.58	8	Dizziness, nausea for 48 hrs.: quite well thereafter: blood bromide 3·5 mg./100 ml. (14.6.58); removed from exposure
3.7.58	5·5	Dizziness only: removed from exposure: blood bromide 0·5 mg./100 ml. by Sept. and not detectable in October
10.7.58	3·6	No symptoms
10.7.58	1·2	No symptoms
10.7.58	0·8	No symptoms
10.7.58	0·8	No symptoms
24.7.58	1·2	No symptoms
31.7.58	0·5	No symptoms
14.8.58	1·6	No symptoms
21.8.58	1·2	No symptoms
21.8.58	1·2	No symptoms
29.8.58	0·4	No symptoms
29.8.59	1·8	No symptoms
12.9.58	3·2	Accidental spillage: no symptoms

prevents the condition from becoming irreversible.

Despite the fact that all cases suffered directly in relation to apparent exposure, only the two most severely affected had any pulmonary signs. Case 1 had a marked bronchorrhoea during the first four days after admission and Case 4 had basal crepitations for three days.

Large doses of intramuscular phenobarbitone and intravenous myanesin were required to control the fits in these two cases. Pulmonary oedema was combated by nursing on a rotor bed to facilitate bronchial drainage, with bronchial aspiration at the first stage of moist lungs.

Most of the cases of poisoning with severe neurological signs seem to be dependent on a sudden exposure to large concentrations, following continuous slight exposure. Such cases usually escape pulmonary oedema, though this is not invariable. Irish, Adams, Spencer, and Rowe (1941), suggested that careful animal investigations might lead to improved treatment in man.

Casualties have continued to increase, as the literature demonstrates.

From the end of August, 1958 to May, 1959, when fumigation was completed, a further 82 men were examined. Bromides were not detected in the blood in any of them, as contrasted with Table 3. The new type canisters were introduced on August 29, 1958.

We should like to express our thanks to Dr. A. Fryberg, Director-General of Health and Medical Services, Brisbane; Dr. A. Pye, General Superintendent, Brisbane and South Coast Hospitals Board; and Dr. O. Powell, Medical Superintendent, South Brisbane Hospital, for permission to publish these cases. Our thanks are due to members of the Government Analyst's Department for the numerous estimations of blood bromides.

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BY

R. L. ZIELHUIS

From the Department of Occupational Medicine, Netherlands Institute for Preventive Medicine, Leyden

(RECEIVED FOR PUBLICATION AUGUST 9, 1960)

In a study of signs and symptoms of lead intoxication in workers in lead processing industries in the Netherlands, use has been made of the apparatus described by Donath (1956) for semi-quantitative determination of coproporphyrin excretion. The significance of this method in the screening of exposed groups of workers has been investigated. The method proved to be a valuable tool in the prevention of inorganic lead intoxication. The frequency distribution of coproporphyrinuria in groups of workers indicates the extent of lead exposure. If the average coproporphyrinuria exceeds 1·5 degrees on the Donath scale there is an increased lead intake. From the frequency distribution of coproporphyrinuria the degree of air pollution with lead and the degree of anaemia due to lead intake may be roughly estimated.

Although the symptomatic occurrence of increased coproporphyrin excretion was established before the beginning of this century, it was a long time before determination of coproporphyrin excretion became a routine screening procedure in the prevention of industrial lead intoxication. Since Vannotti (1937) numerous authors have been of the opinion that coproporphyrinuria is a constant early sign of increased inorganic lead intake. Goldblatt and Goldblatt (1956), for instance, state that a workman does not suffer from lead intoxication if the coproporphyrin excretion consistently stays within normal limits. A normal coproporphyrinuria is therefore of great significance in evaluating lead exposure.

Increased coproporphyrinuria is a sensitive sign of lead absorption. It occurs very early, before basophilic punctated erythrocytes appear or the haemoglobin decreases. A close correlation with clinical symptoms cannot be established in individuals, presumably because of the extreme sensitivity: a subjectively latent lead intoxication causes an increased coproporphyrinuria long before the haemoglobin value decreases. In groups, however, Pinto, Einert, Roberts, Winn, and Nelson (1952) found a correlation between the occurrence of subjective symptoms and coproporphyrinuria ($>400\gamma$/l.). The same is true for the correlation between urinary excretion of lead and coproporphyrin (Waldman and Seideman, 1950; Johnson and Whitman, 1950; Harrold, Meek, and Padden, 1952; Gupta and Iyer, 1954). It may even be true that an increase in coproporphyrin excretion occurs earlier than an increase in lead excretion, as observed by the present author in animal experiments (Zielhuis, 1959a).

Normal values in non-exposed persons have been established by several authors, most of whom accept 200γ/l. as the upper limit of normal. Few of these authors, however, suggested "danger-levels" to be used as criteria in the prevention of lead intoxication. Those which are mentioned differ greatly.

Method

One of the difficulties which had to be overcome before determination of coproporphyrin excretion could constitute a routine screening procedure was the need for a less elaborate method of quantitative determination in urine. Only after Hijmans van den Bergh and Grotepass (1933) evolved their semi-quantitative method (estimation of the degree of fluorescence in ultra-violet light after extraction in ether-glacial acetic acid) could the use of increased coproporphyrinuria in the practice of industrial hygiene be accepted. Several semi-quantitative methods came into use which were based on Hijmans van den Bergh's method, but in more or less modified form (Wyllie, 1955). In most cases, however, subjective estimation of the degree of fluorescence (*e.g.* 0, +, ++, +++, and so on) made comparison of results an inaccurate procedure. In the Netherlands Institute for Preventive Medicine at Leyden, Donath (1956) constructed an apparatus which made objective

TABLE 1

COPROPORPHYRINURIA ESTIMATIONS (DONATH SCALE) IN RELATION TO LEAD-IN-AIR CONCENTRATIONS AND DURATION OF EXPOSURE IN 157 WORKERS FROM LEAD PIGMENT FACTORIES A AND B

Lead-in-Air Concentrations (mg. Pb/m.³)		Duration of Exposure												Total Workers Median Coproporphyrinuria and (range)	
		0-6 months		7-12 months		1-5 years		6-10 years		11-20 years		>20 years			
		A	B	A	B	A	B	A	B	A	B	A	B	A*	B
0·05	Number of workers	2	4	—	2	—	2	2	—	1	1	—	6	5	15
	mean	1·0	1·2	—	2·5	—	1·5	1·5	—	1	1	—	1·3	1	1
	(range)	(1-1)	(1-2)	—	(2-3)	—	(1-2)	(1-2)	—	(-)	(-)	—	(1-2)	(1-2)	(1-3)
0·05-0·15	Number of workers	7	4	5	8	15	11	11	8	4	10	5	10	47	51
	mean	3·1	2·0	2·4	2·9	3·6	2·2	3·2	2·1	3·5	3·3	3·2	2·3	3	2
	(range)	(1-4)	(1-3)	(1-4)	(1-5)	(3-6)	(1-4)	(1-7)	(1-3)	(1-5)	(1-5)	(2-4)	(1-4)	(1-7)	(1-5)
0·15-0·65	Number of workers	—	1	3	4	6	2	7	1	—	2	3	1	19	11
	mean	—	5	5·0	5·0	5·5	4·5	4·0	2	—	4·5	4·3	6	5	5
	(range)	—	(-)	(3-7)	(3-6)	(5-6)	(3-6)	(2-7)	(-)	—	(4-5)	(3-6)	(-)	(2-7)	(2-6)
0·65	Number of workers	—	—	2	2	2	—	1	—	1	1	—	—	6	3
	mean	—	—	6·0	5·5	5·0	—	5	—	5	5	—	—	5·5	5
	(range)	—	—	(6-6)	(5-6)	(4-6)	—	(-)	—	(-)	(-)	—	—	(4-6)	(5-6)

* Owing to frequent transfer it was not possible to make reasonable estimates of the exposure of four of the 81 workers in Factory A.

semi-quantitative determination possible. In this method 10 ml. of recently voided urine are shaken in a test-tube with 2 ml. ether-glacial acetic acid and the fluorescence of the foamy ether layer in ultra-violet light is compared with the fluorescence of eight specially prepared small circular pieces of paper mounted on a rotating disc. The intensity of fluorescence on this scale corresponds with the following logarithmically increasing coproporphyrin concentrations: degree 1: 0-50γ/l., 2: 50-100γ/l., 3: 100-200γ/l., 4: 200-400γ/l., 5: 400-800γ/l., 6: 800-1600γ/l., 7: 1600-3000γ/l. and 8: 3000-5000γ/l. With a minimum of instruction this apparatus can be used to determine the degree of coproporphyrinuria easily and quickly on the factory premises; it yields reliably reproducible results with a negligible variability due to observer error (Donath, 1955). The urine of at least 30 persons can be examined in half an hour.

The Present Investigation

In 112 males not exposed to lead, most of them industrial workers, approximately 70% showed a coproporphyrinuria degree 1 on the Donath scale (0-50γ/l.), 20% degree 2 (50-100γ/l.), and 10% degree 3 (100-200γ/l.). This frequency distribution was presumed to be "normal" and was also consistent with the data in the literature. The "normal" average of this group $\left(\frac{\sum \text{coprop.}}{n}\right)$ was 1·4 degrees.

In several investigations in many lead processing factories a total of 513 workers with a varied exposure to lead were examined. In two factories (A and B), each producing lead pigments (mainly lead chromate, lead sulphate, and lead stearate) in 1957 and 1958, lead-in-air concentrations were determined by the section for Industrial Hygiene of the Central Netherlands Organization for Applied Research (T.N.O.) and in the same period the workers (81 in factory A, 80 in factory B) were examined by the author. Table 1 gives coproporphyrinuria estimations on the Donath scale, related to intensity and duration of exposure.

From this Table it can be seen that workers (n = 20) exposed to less than 0·05 mg. Pb/m.³ never had a coproporphyrinuria >3 on the Donath scale (100-200 γ/l.); with increasing lead-in-air concentrations the coproporphyrinuria also increased: except in two cases all the workers (n = 39) with an exposure to >0·15 mg. Pb/m.³ had a coproporphyrinuria $\geqslant$3; and finally there was no increase in coproporphyrinuria with increasing duration of exposure.

Table 1 includes only those workers about whom there was a reasonable knowledge of duration and intensity of exposure in the past.

We may disregard the work history and correlate the frequency distribution of coproporphyrinuria in groups of workers of factories A and B with the lead-in-air concentration present at the time of examination. This is done in Fig. 1, in which a group of workers never occupationally exposed to lead has also been included. In the group exposed

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0·05	Number of workers	2	4	—	2	—	2	2	—	1	1	—	6	8	15
	Coproporphyrinuria mean	1·0	1·2	—	2·5	—	1·5	1·5	—	1	1	—	1·3	1	1
	Coproporphyrinuria (range)	(1-1)	(1-2)	—	(2-3)	—	(1-2)	(1-2)	—	(-)	(-)	—	(1-2)	(1-2)	(1-3)
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	Coproporphyrinuria (range)	(1-4)	(1-3)	(1-4)	(1-5)	(3-6)	(1-4)	(1-7)	(1-3)	(1-5)	(1-5)	(2-4)	(1-4)	(1-7)	(1-5)
0·15-0·65	Number of workers	—	1	3	4	6	2	7	1	—	2	3	1	19	11
	Coproporphyrinuria mean	—	5	5·0	5·0	5·5	4·5	4·0	2	—	4·5	4·3	6	5	5
	Coproporphyrinuria (range)	—	(-)	(3-7)	(3-6)	(5-6)	(3-6)	(2-7)	(-)	—	(4-5)	(3-6)	(-)	(2-7)	(2-6)
0·65	Number of workers	—	—	2	2	2	—	1	—	1	1	—	—	6	3
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to <0·05 mg. Pb/m.³ some workers were included who had recently been transferred from departments with higher exposure, and some of them still showed a moderately increased coproporphyrinuria (*cf.* Table 1). The correlation coefficient for lead-in-air

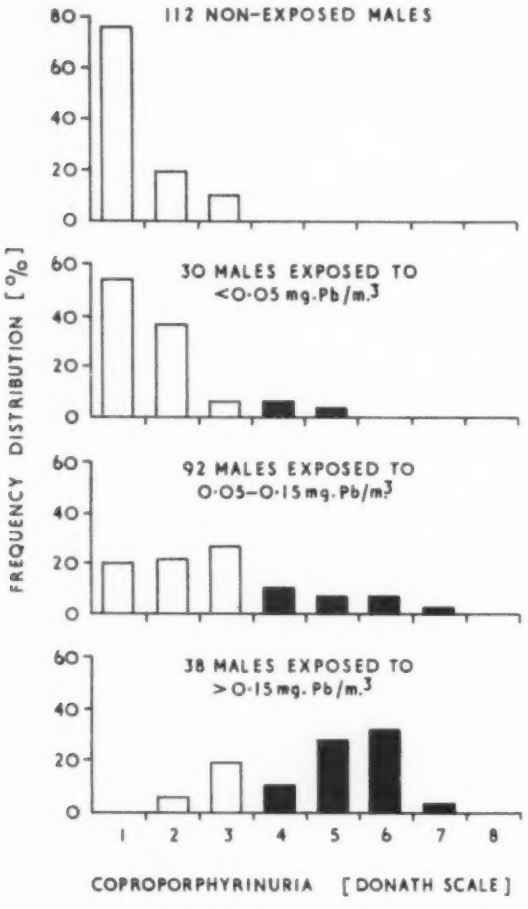

FIG. 1.—Frequency distributions of coproporphyrinuria in relation to lead-in-air concentration. The exposed subjects were all working in two lead pigment factories.

concentrations with individual values of coproporphyrinuria was in factory A, 0·478 ($p<0·001$) and in factory B, 0·510 ($p<0·001$). By means of the frequency distributions of coproporphyrinuria it is therefore possible to make a rough estimate of the lead-in-air concentrations in a department. The determination of coproporphyrinuria in a group of workers provides a method of obtaining a first impression of the conditions in a lead processing factory.

Some examples of such frequency distributions in different industries are given in Fig. 2, which also shows the distributions of haemoglobin values. In Fig. 2 a deviation to the right is seen for both coproporphyrinuria and haemoglobin frequency distributions. Haemoglobin was determined with the Siccahaemometer. For 16 groups of workers the average coproporphyrinuria values $\left(\frac{\Sigma \text{coprop.}}{n}\right)$ and the percentage of individuals with haemoglobin ≤13·7 g./100 ml. were calculated (*i.e.* those with low haemoglobin values). Each group consisted of more than 20 workers (Table 2 and Fig. 3). The correlation between the percentage with low haemoglobin and raised coproporphyrinuria is high ($r=0·91$). The frequency distribution of coproporphyrin values therefore gives some indication of the degree of anaemia in the same group of workers.

Because in chronic exposure to lead a decrease in haemoglobin usually precedes the occurrence of subjective symptoms, prevention of anaemia is at the same time prevention of manifest intoxication. In non-exposed workers of the same socio-economic status in factories A and B we found 25% with haemoglobin ≤13·7 g./100 ml. An increase in frequency of low haemoglobin values in exposed groups may be regarded as due to lead intake. From Fig. 3 it may be concluded that the normal frequency of 25% is surpassed if the average coproporphyrinuria exceeds 2 to 2·5 on the Donath scale (*e.g.* 50-100γ/l.). This value, therefore, may be regarded as the maximum allowable coproporphyrinuria in *groups* of workers. This maximum allowable average coproporphyrinuria of 2 to 2·5 corresponds to a lead-in-air concentration of about 0·1 mg. Pb/m.³ (Zielhuis, 1959b), at least under the conditions which prevail in lead pigment industries in the Netherlands.

A coproporphyrinuria of 8 on the Donath scale has never been found, even in manifest intoxication. This probably does not mean that the coproporphyrinuria did not exceed 3000γ/l., but that the discrimination between degree 7 and 8 is dubious, because the increase in intensity of fluorescence approaches a horizontal level. A modification of the scale of Donath is therefore suggested: degree 7 may be regarded as coproporphyrinuria ≥1600γ/l.

Discussion

From the foregoing data some conclusions for the practice of industrial hygiene may be drawn. The frequency distribution of coproporphyrin values in *groups* of workers gives the following information:

(a) If the average coproporphyrinuria exceeds 1·5 degrees on the Donath scale there is an increased lead intake.

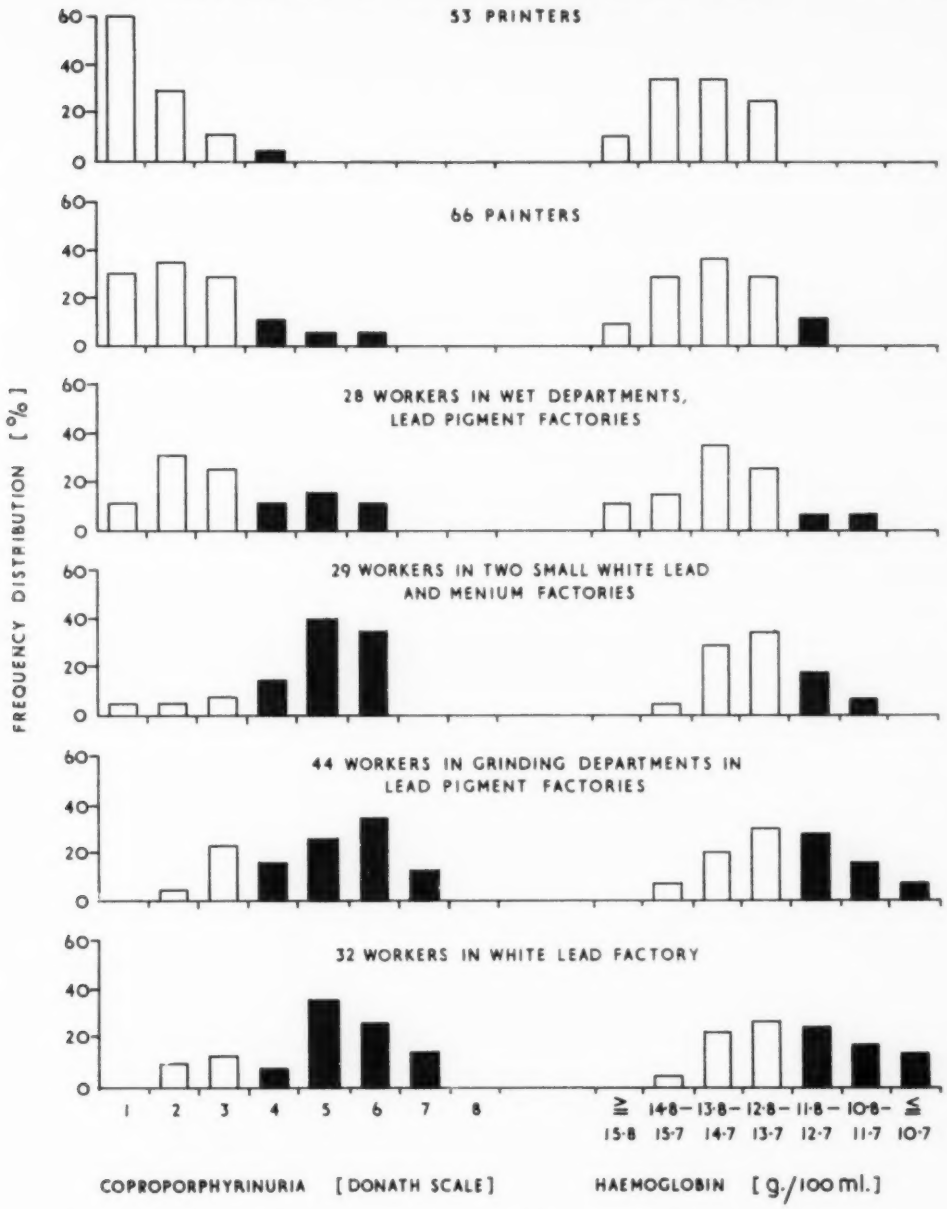

FIG. 2.—Frequency distributions of coproporphyrinuria and haemoglobin in different groups of workers.

(b) If the average coproporphyrinuria lies between 1·5 and 2·5 degrees the exposure is within allowable limits.

(c) If the average coproporphyrinuria exceeds 2·5 degrees the maximum allowable concentration for lead in air (0·1 mg. Pb/m.^{3}) has probably been surpassed.

(d) From the frequency distribution of coproporphyrinuria the degree of air pollution with lead and the degree of anaemia due to lead intake may be roughly estimated.

These conclusions are valid for groups of workers numbering 20 or more. Plotting the values on a floor plan of the factory may lead to the discovery of areas of high lead exposure.

TABLE 2

SIXTEEN GROUPS OF WORKERS: AVERAGE COPROPORPHYRINURIA ESTIMATIONS AND PERCENTAGES OF PERSONS WITH HAEMOGLOBIN OF 13·7 g./100 ml. OR LESS

Group	No. of Persons	Average Coproporphyrinuria (Donath Scale)	% Persons with Haemoglobin ≤ 13·7 g./100 ml.
Males not exposed to lead	112	1·4	4
Printers	53	1·5	23
Workers exposed to <0·05 mg. Pb/m³ (Fig. 1)	30	1·8	33
Production department workers for non-lead-pigments	27	2·1	33
Maintenance department workers in lead pigment factories	61	2·3	24
Painters	66	2·4	33
Ship-yard welders	44	2·7	46
Workers exposed to 0·05-0·15 mg. Pb/m.³ (Fig. 1)	92	3·0	32
Wet department workers in lead pigment factories	28	3·2	39
Lead burners and welders	36	4·4	47
Ship-yard ship cleaning workers	37	4·5	89
Workers exposed to >0·15 mg. Pb/m.³ (Fig. 1)	38	4·7	74
Workers in two small white lead and menium factories	29	4·8	69
White lead factory workers	32	4·9	75
Grinding department workers in lead pigment factories	44	4·9	76
Workers in small accumulator factories	21	5·0	62

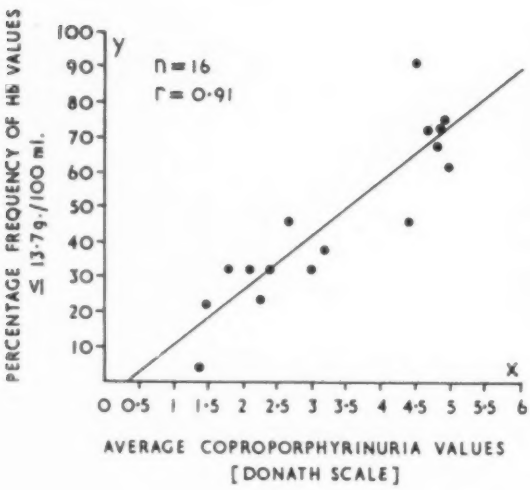

FIG. 3.—Correlation between low haemoglobin values and coproporphyrinuria in 16 groups of workers. $y = 6{\cdot}5 + 16{\cdot}1x$.

If the coproporphyrinuria values of the group are generally within normal limits or are only slightly increased, no danger of manifest lead intoxication exists, and determination of the number of basophil punctated erythrocytes or haemoglobin is not necessary because disturbance of function (*i.e.* anaemia) is not likely to take place. If the coproporphyrinuria values, however, exceed the allowable range, individual counting of basophils and haemoglobin is necessary. In that case, the individual values for coproporphyrinuria cannot be the only criteria, as in an individual the degree of coproporphyrinuria does not indicate sufficiently accurately the extent of lead absorption, except in a negative sense: normal coproporphyrin excretion generally indicates absence of increased lead absorption.

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EROSION OF THE TEETH DUE TO SULPHURIC ACID IN THE BATTERY INDUSTRY

BY

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From Chloride Batteries Limited

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This paper examines the effects of sulphuric acid on the teeth of workers in the storage battery industry. The manufacturing processes are described. A statistical analysis is given of the findings in a group of workers exposed to acid and an unexposed control group.

It is found that only men exposed to acid mist display erosion of the incisor teeth and that the degree of erosion is classifiable into four groups. The clinical picture of each group is described. There is progressive destruction of the tooth crown from direct impingement of acid droplets. Advanced cases show almost complete loss of crown. Erosion ceases when lip level is reached. The erosion process is painless.

The factors influencing the degree of erosion are investigated. These seem to be: length of exposure, lip level, and concentration of acid in the air.

The differential diagnosis from other causes of tooth destruction is given. The findings of other workers in the field are compared.

Several methods of prevention are discussed.

There are a number of previous descriptions of the effects of various acids on the teeth, under industrial conditions. Few of the writers have had the opportunity of observing a large group of people exposed over a long period.

The effects on the teeth of workers exposed to acid fumes, mists, and dusts have been described previously (Berenzon, 1931; Schour and Sarnat, 1942; Ludewig, 1941; Lynch and Bell, 1947; Dale and McCauley, 1948; Elsbury, Browne, and Boyes, 1951; *New England Journal of Medicine*, 1940).

The present investigation was undertaken to examine the effects of sulphuric acid mist on the teeth of workers in the battery industry. The processes which involve exposure to acid are known as forming and charging.

Description of Processes

Forming.—Lead battery plates are immersed in tanks of dilute sulphuric acid. The plates are then joined together in groups to give a positive and negative pole. Direct current of 110 volts is passed through the circuit, which "forms" the plates.

The tanks measure approximately 3 × 2 ft. and there are usually 36 tanks to each circuit, giving a very large surface area of acid solution. The department (Fig. 1), which is all under one roof, measures approximately 120 × 40 yds. Three jack roofs running the full length of the department give good natural ventilation. Air inlet is through side windows and doorways. No successful forced draught has been possible, due to acid corrosion of equipment and the very large area which has to be covered.

During the forming process, small gas bubbles carry a spray of acid mist into the atmosphere (Fig. 2). The concentration of the mist in the department varies with weather conditions, being greatest when there is no wind and when the atmosphere is damp and foggy.

Charging.—This process consists of filling finished batteries with acid and charging them by means of direct current.

The process is similar in effect to forming, but the fact that the battery cells now have lids reduces the acid concentration in the air and it never amounts to a visible mist as it does in the forming department.

Acid Concentrations

Forming.—The mist is a mixture of dilute sulphuric acids of specific gravity varying from 1·020 to 1·100.

The amount of acid in the air, expressed as pure sulphuric acid, varied from 3·0 mg. to 16·6 mg./cu.m. air. These measurements were made on a dry day with low relative humidity, using "teepol" and ebonite sheets. The amount of acid present on a cold humid day often exceeds 16 mg./cu.m. air.

FIG. 1.—Forming shed, showing tanks with ebonite covers in position.

Charging.—The specific gravities of the acids used in charging are higher than in forming and are mostly about 1·265.

The amount of acid in the atmosphere expressed as pure sulphuric acid varies from < 0·8 mg. to 2·5 mg./cu.m. air.

The standard error of the method used is ± 25%.

Method of Survey

The entire staffs of the forming and charging departments, 160 men, were examined. Those having any standing anterior teeth were then re-examined in greater detail, paying close attention to the effect on all teeth, the degree to which each tooth was affected, oral hygiene condition, decayed, missing, and filled (D.M.F.) rates, relation of resting lip levels to the level of erosion, breathing habits, and medical history, if relevant.

A control group of 117 men consisted of all the men in two other departments, free from acid mist or any other industrial dental hazard. These two departments were Inspection, where the component parts of batteries are inspected, and Packers, where completed batteries are packed for despatch. This group was statistically comparable, being of similar mean age, age spread, and social and financial status to the forming and charging groups.

In measuring the degree of erosion, any assessment of the amount of tooth loss must be empirical, as the original dimensions of the affected teeth are unknown.

At the preliminary examination, the degree to which the teeth were affected seemed to fall roughly into four groups and the following classification was therefore adopted for the second examination:

(a) *Attrition.*—Some cases showed loss of tooth substance caused by traumatic occlusion or attrition of the anterior teeth caused by lack of posterior teeth and failure to wear partial dentures.

(b) *Etching* of the labial enamel without loss of tooth substance.

(c) *Group* 1 *Erosion:* loss, not exceeding 0·2 (2 mm.) of incisal enamel.

(d) *Group* 2 *Erosion:* loss of 0·2 to 0·5 of tooth crown.

(e) *Group* 3 *Erosion:* loss of more than 0·5 of tooth crown.

Once Group 1 Erosion has been reached the anterior teeth are no longer in occlusion and attrition of the incisors will not take place.

Of the men from the forming department who had full dentures, a number gave a clear history of erosion prior to extraction. As such history was based on hearsay evidence only, these cases could not be classified with accuracy and so were not included for statistical analysis.

Consideration of the incidence of erosion, etc. among the three groups must naturally be restricted to men with teeth. Thus, of the 63 men at risk in forming only six were free from etching, erosion, or attrition; whereas 33 of the 44 men at risk in the

control group did not have any of these defects. This difference is highly significant ($p<0.0001$).

Only men who had been exposed to acid mist suffered from etching or erosion of the teeth and only men from the forming department had either Group 2 or Group 3 Erosion (Table 2). Of the 63 men in this department with teeth, 55 had etching or erosion compared with seven of the 15 men in the charging department, a significant difference ($p<0.01$).

TABLE 1

FINDINGS AMONG THE FORMING, CHARGING, AND CONTROL GROUPS

Condition of Teeth	Forming		Charging		Controls	
	No.	%	No.	%	No.	%
Dentures	66	51·2	16	51·6	73	62·4
Erosion, etching, and attrition	57	44·2	9	29·0	11	9·4
No erosion, etching, or attrition	6	4·6	6	19·4	33	28·2
Total in group	129	100·0	31	100·0	117	100·0
Mean age in years	47·6		43·4		45·0	
Standard deviation	11·3		12·3		10·2	

TABLE 2

EROSION, ETCHING, AND ATTRITION IN FORMING, CHARGING, AND CONTROL GROUPS

Condition of Teeth	Forming (No.)	Charging (No.)	Controls (No.)
Not affected	6	6	33
Attrition	2	2	11
Etching	13	4	0
Group 1 erosion	16	3	0
Group 2 erosion	16	0	0
Group 3 erosion	10	0	0
Total number with teeth	63	15	44

TABLE 3

ORAL HYGIENE AND DEGREE OF EROSION IN MEN IN FORMING DEPARTMENT

Oral Hygiene	No Erosion	Degree of Erosion				
		Etching	Group 1	Group 2	Group 3	Total
Good	1	7	2	1	3	14
Fair	1	2	6	6	5	20
Poor	6	4	8	9	2	29

TABLE 4

DEGREE OF EROSION, AGE, AND LENGTH OF EXPOSURE OF MEN IN FORMING DEPARTMENT

	No Erosion	Etching	Group 1	Group 2	Group 3	Dentures
No. of men	8	13	16	16	10	66
Mean age (years)	48·1	35·1	40·5	43·9	44·5	47·6
Mean exposure (years)	14·6	4·9	7·1	12·3	16·6	21·3

In addition to the groups listed in Table 1, a small group of seven men transferred from the forming department of a subsidiary factory, was examined. One had dentures, three displayed Group 2 Erosion, and three Group 3 Erosion. This group had a mean length of exposure of five years, which is far less than at the main factory (Table 4).

FIG. 2.—A forming tank, showing "formation" of plates in acid solution.

The Clinical Picture

The clinical picture is typical. The teeth affected were invariably the centrals and laterals on their labial surfaces. Canines were affected to a much smaller extent. No effect was observed on premolars, molars, or the lingual surfaces of any anterior teeth. Upper and lower teeth were affected in equal numbers.

The initial lesion is an etching of the labial surface of the enamel below the lip-line, *i.e.* in the incisal one third of the tooth crown. This gives a dull ground-glass appearance barely visible to the naked eye, but with a sharp line of demarcation from the normal shiny enamel. This is quite different in appearance from the erosion of enamel which precedes cervical caries and which is chalky in both colour and texture, grossly pitted, and invariably at the gingival third of the crown.

Etching is then followed by loss of tooth substance, beginning at the mesio-incisal angle of the central incisors and then spreading to involve the whole of the incisal edge. The surface thus exposed may be highly polished or etched. Because of the greater loss of enamel from the mesial angle than the distal and from the labio-incisal than the linguo-incisal, the incisal edge slopes downwards from the mesial to distal and from the labial to lingual. The junction between the labial and incisal surface (the labio-incisal line angle) is also rounded. This is in direct contrast to cases of physiological attrition, in which the angle is sharp. The picture thus presented is typical and almost diagnostic of Group 1 Erosion (Fig. 3).

With the erosion of the incisal edges, a slight degree of anterior open bite is established. Further loss of tooth substance occurs, partly because of direct wear from biting, but mainly because of progressive erosion from direct impingement of acid droplets on to the tooth surface. This is borne out by the fact that early wear takes the incisors out of occlusion and eliminates loss from direct attrition.

As erosion progresses, more enamel is lost from the incisal edge and the dentine begins to show through the thinned enamel as a white fleck. The tooth crown is shortened and, as still more incisal edge is lost, the dentine becomes exposed. This shows as a deeply stained line, which is usually black or brown, between the two enamel plates. The greater loss of enamel at the labio-incisal line angle, together with the shortening of the crown, gives the tooth a bulbous appearance (Fig. 4). In the advanced cases of Group 3 Erosion, there is almost complete loss of the crown and the "incisal" surface is flat, smooth and shiny, and slopes obliquely (Fig. 5). The inner structure of the tooth is plainly visible in oblique section and the dentine is often a dark red-brown colour. Erosion seems to stop completely when lip level is reached.

In 10 cases, a somewhat different pattern was noticed. Erosion seemed to take place simultaneously over the greater part of the labial surface of the incisors, instead of the incisal edge only. This produced a chisel-shaped tooth with a smooth labial surface and sharp incisal edge (Fig. 6). There was no evidence of trauma to the soft tissues or the tongue in these cases.

None of the men affected by etching or any of the degrees of erosion had experienced pain or sensitivity at any stage. This is presumably due to the laying down of secondary dentine in the pulp chamber as erosion progresses. In one case, however, erosion was so rapid that the pulp was exposed and an apical abscess occurred.

Influence of Other Factors

Oral Hygiene.—Oral hygiene was classified as follows: Good—little or no superficial stain; fair—some deposits of calculus present; poor—large deposits of supra- and sub-gingival calculus.

There is no obvious evidence that oral hygiene has an influence on the degree of erosion. Both materia alba and calculus can be dissolved completely *in vitro* by sulphuric acid and it might be assumed that, *in vivo*, the acid spray would dissolve supra-gingival calculus and give a higher standard of oral hygiene. This is not the case, because the acid mist does not reach those parts of the teeth covered by the lips and cheeks and the lingual surfaces of the incisors and it is here that calculus first collects. In people exposed to acid mist, the exposed surfaces of the teeth are invariably clean and free from materia alba as far down as lip levels.

Age and Length of Exposure.—It is evident that the degree to which a man's teeth are affected is directly influenced by the length of time spent in the department, although one man exhibited Group 2 Erosion after only six months; this was a most unusual case. On the other hand, it seems likely that some men are completely immune. Table 4 shows that eight men had no erosion after an average exposure of nearly 15 years, although the average exposure of those showing etching was five years. It should be mentioned that most of the men in the forming department had been working there for several years before the survey was made and may well have exhibited etching soon after starting. This is borne out by later observation on new employees, many of whom exhibited definite etching after three or four months' exposure.

D.M.F. Rates.—The D.M.F. rate is the number of decayed, missing, and filled teeth expressed as a percentage of 32 and is a guide to the degree of resistance to caries. There was no evidence of any relation between this rate and the degree of erosion.

Lip Levels.—The levels of etching or erosion were observed whilst the patients' lips were at normal rest positions, *i.e.* with teeth and lips slightly parted. In all cases there was a sharp line of demarcation between eroded and normal enamel coincident with the lip-line. Men with markedly short lips showed gross erosion.

It does seem that the length of lips has a direct bearing on the degree of erosion. Only the surface of the teeth uncovered by lips and cheeks is affected. The lips provide a direct shield from the acid spray and also bathe the teeth with protective saliva. Thus the teeth beyond the canines are never affected and erosion ceases at lip level. It is also significant that

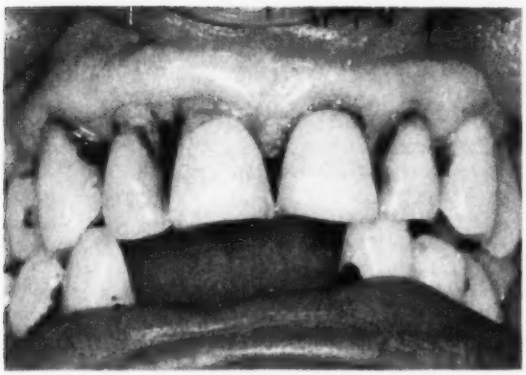

FIG. 3.—Group 1 Erosion, showing rounding of incisal edge. Note gum recession on 321 exposing cementation.

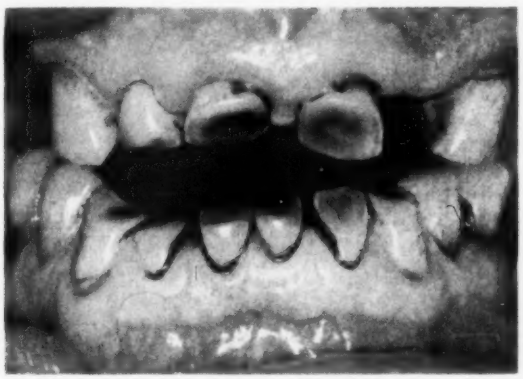

FIG. 5.—Group 3 erosion.

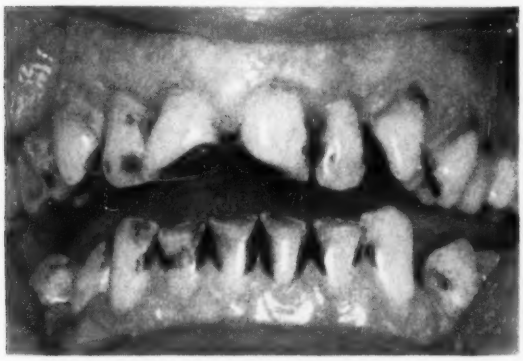

FIG. 4.—Group 2 bulbous erosion.

FIG. 6.—Group 3 "chisel" type erosion.

erosion seems to begin at the mesio-incisal angle of the central incisors where the lip level is highest.

Previous Medical History.—Only two men gave a history of chronic nasal catarrh sufficient to cause habitual mouth breathing. Obvious mouth breathers are excluded from working in the department.

Concentrations of Acid in the Air.—In the forming department 55 (87%) of the men with standing teeth were affected, whereas in the charging department only seven men out of 15 showed any evidence of attack by acid, with only three showing actual erosion. The acid exposure of the charging group was much less (see above) and so was the degree of erosion. It is probable, therefore, that a certain amount of acid in the air is necessary to cause erosion.

Six men from the forming department were unaffected by acid and did not show attrition. This could be due either to the resistance of the particular enamel or, alternatively, to these individuals seldom parting their lips and so allowing acid spray to reach the teeth. This factor cannot, of course, be measured.

Dentures.—Some of the men in the forming department stated that, before having total extractions and acquiring dentures, their anterior teeth were eroded. In spite of this, we found that 51% of the men in the forming department had dentures against 62% of the controls. This suggests that erosion of the teeth was seldom, if ever, the sole reason for acquiring dentures. Although the difference is not statistically significant ($p = 0{\cdot}1$), it is possible that exposure to acid vapour does in fact help to preserve the teeth. It is known that acid dissolves calculus and could thus have improved the self-cleansing of the teeth. Our observations suggest, however, that calculus is only dissolved where erosion takes place and, therefore, only tends to

protect the incisors. It is possible that the erosion, producing smooth shiny areas, renders the incisors self-cleansing and more immune to carious attack. Certainly no caries of anterior teeth was ever observed in any of the affected men.

Discussion

Our observations on this group of men exposed to sulphuric acid mist leave no doubt that the erosion of the incisors is due to the direct impingement of fine droplets of acid. The teeth beyond the canines are not exposed to direct impingement of acid mist and are also more constantly bathed by saliva.

The parts of the incisors which are normally covered by the lips are never eroded and this is the reason why the cervical areas are unaffected, although the enamel is thinnest here.

This type of erosion is similar to that produced in industry by other acids including hydrochloric, nitric, and tartaric. Hydrofluoric acid does not produce erosion despite the fact that, during its manufacture, there is a high percentage of sulphuric acid in the atmosphere (Dale and McCauley, 1948). Hydrofluoric acid affords some protection against sulphuric acid erosion.

The sulphuric acid erosion described is characteristic in appearance. It is easily distinguished from caries, which produces soft circumscribed areas with undermined edges, and from attritions and abrasions of the teeth. The condition attributed to acid erosion by some authors (Thoma and Robinson, 1955) is almost certainly gross cervical caries.

Attrition is commonly seen in persons who have traumatic occlusions. Abrasion of the teeth is commonly seen in pipe smokers and upholsterers, shoemakers, seamstresses, glass-blowers, etc. Both attrition and abrasions can easily be distinguished by their obvious cause, the wear being limited to areas of contact between the teeth, and by the production of shiny facets with sharp margins. This is in direct contrast to the rounded margins seen in acid erosion.

Acid erosion of non-industrial aetiology is not uncommon, the main causes being: regurgitation of vomit (Burket, 1957), medicinal drinking of dilute hydrochloric acid, and excessive consumption of citrus juices and fruit drinks (Finch, 1957; Hicks, 1950; Stafne and Lovestedt, 1947).

These non-industrial erosions differ markedly from the industrial erosions. The lesions produced are shiny, smooth, disc-shaped, shallow cavities affecting principally the cervical areas of the teeth. Hypersensitivity is often a marked feature.

Misch (1923), in a report on industrial erosions in Germany, claims that the condition produces numbness in the teeth affected and later severe pain. He also claims that the teeth become very brittle. In these respects, our findings differ; we have found no evidence of pain, or even sensitivity to temperature extremes, in any cases at any stage of erosion, and we have never seen any sign of tooth breakage, which one would expect if erosion produced brittleness. We maintain that loss of tooth substance is due to gradual erosion by direct impingement of acid mist on the exposed tooth surfaces.

Prevention

In the forming department, owing to the very large area of some 1,200 acid tanks, each of approximately 3 × 2 ft. surface area, the task of ventilation is extremely difficult. Attempts have been made to reduce the spray by the use of "teepol". This causes a foam on the top of the acid and the gas bubbles then coalesce in the foam.

Ebonite sheets have been used to cover the tanks and these cause condensation of the spray and the acid then runs back into the tanks. Both these methods have reduced considerably the amount of spray in the atmosphere.

Total enclosure might be possible and an attempt is to be made to see if this is practicable. Ventilation of the department appears to be a major factor in prevention.

The small group of seven men transferred from a subsidiary factory all showed advanced erosion more rapidly, probably because working conditions and ventilation were poor. Similarly, during the war years, when ventilation was of necessity restricted, there appears to have been more rapid erosion.

In some small forming departments in other battery firms, where side walls have been left out of the buildings, there is a lower concentration of acid in the air, due to much better air flow, and little or no erosion is seen. Such construction is, however, impracticable in a large factory.

Protection of the incisor teeth with fitted plastic splints lined with magnesia has been tried. These splints are somewhat uncomfortable to wear for long periods and the men quickly stopped using them.

Alkaline mouth washes do not give any lasting protection and no drinking or chewing is permitted, on account of the lead hazard. The chewing of "oralgene" gum, or alkaline tablets advocated by Hentze (1925) is therefore impracticable. The use of celluloid face-shields is being instituted. This should afford a certain amount of protection by preventing the acid droplets from impinging directly on the teeth. It is felt that the only method of giving direct protection to the teeth is by the use

of a mouthwash or dentifrice which will deposit a protective film on the enamel and remain effective for at least four hours. Several substances are being investigated currently.

We should like to express our thanks to the management of Chloride Batteries Limited, for allowing us to carry out this survey; to the foremen of the departments for their help and particularly to all the men we surveyed, who were so co-operative and gave us so much of their time. We should also like to thank Mr. John Slater of the Chloride Electrical Storage Company Ltd., Research and Development Department for the measurement of the acid concentrations in the atmosphere; and Mrs. White and Miss Clayton for their help in arranging interviews and collecting much of the background information. Finally, we wish to thank Miss I. Dingwall Fordyce, of the Department of Occupational Health of Manchester University, for all her help in the preparation of the statistics, and the Department of Medical Illustration of Manchester Royal Infirmary for the photographs of the teeth.

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OBSERVATIONS ON THE URINARY PROTEIN OF MEN EXPOSED TO CADMIUM DUST AND FUME

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Urinary protein from five cadmium workers has been examined, two men exposed to cadmium dust and three to cadmium fume. No difference was discernible between the two groups in regard to the quantity of protein excreted (10 to 36 times the average normal) or to the chemical composition and molecular weight of the protein. Cadmium urinary protein exhibits a complex electrophoretic pattern on paper, with five components. These have mobilities similar to the five main fractions of serum. All their molecular weights, however, are in the range 20 to 30,000. Filter paper electrophoresis showed a preponderance of globulins, especially α_2, over albumin. On column electrophoresis, however, a relatively higher proportion of albumin appeared, due probably to a change of mobility of a heat incoagulable protein, which constituted 20 to 25% of the whole. The heat incoagulable protein had a high content of glycine, serine, hexose, methylpentose, and sialic acid. Electrophoretic fractions 1 and 2 of the urinary protein were similarly rich in glycine, serine, hexose, methylpentose, and sialic acid, possibly due to presence of heat incoagulable protein. The presence of two components in fraction 1 became evident from ultracentrifugal studies. Plasma proteins could be demonstrated immunologically in the urine, but the relative proportion present could not be assessed. Urinary proteins associated with cadmium absorption include components of low molecular weight and high carbohydrate content similar to those which have been observed in normal urine. The distinctive feature of the proteinuria appears to be the presence of a low molecular urinary albumin, the origin of which is the subject of further study.

Small quantities of protein can be recovered from normal urine (McGarry, Sehon, and Rose, 1955; Webb, Rose, and Sehon, 1958a). The occurrence of abnormally increased proteinuria in men chronically exposed in industry to cadmium oxide dust was first described by Friberg (1950). Similar findings were reported by Baader (1951) and Smith, Kench, and Lane (1955). A high incidence of proteinuria in men exposed to cadmium fume has also been observed (Bonnell, 1955; Smith and Kench, 1957).

The urinary protein associated with inhalation of cadmium oxide dust or fume is of special interest in that, although it has been shown to comprise several components electrophoretically, the molecular weight was consistently in the range 20-30,000 (Friberg, 1950; Kekwick, 1955). This feature of the cadmium urinary protein encouraged us to consider that this protein might be a specific product of cadmium poisoning, a consequence of a metabolic disturbance induced by cadmium. Accordingly this possibility has been explored and the present paper describes electrophoretic behaviour and chemical analysis of the various components of the cadmium urinary protein.

Whilst our investigations were proceeding, it was shown by Webb *et al.* (1958a, b) that globulins occurring in traces in normal urine are of low molecular weight and, as will be clear from our present report, are also similar in other ways to the protein excreted in the urine of cadmium workers.

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Materials and Methods

The five men chosen for study were all excreting protein in quantities greater than 1 g. l. Two (D1 and

D2) were engaged in the manufacture of alkaline accumulators and were exposed to cadmium oxide dust. The other three (F1, F2, and F3) were employed in the production of cadmium-copper alloy; F1 and F2 at one foundry and F3 at a second. D1 and F1 were excreting large quantities of cadmium and D2 and F2 relatively small quantities. F3 was the only worker at Foundry II excreting protein in amounts above the chosen minimum and his cadmium excretion was intermediate between these two pairs.

Urinary specimens were collected at mid-morning, directly into wide-necked pyrex bottles of 400 ml. capacity, previously cleaned and sterilized by heat. Each bottle contained a small crystal of thymol to minimize bacterial growth during transit to the laboratory. Examination of urinary specimens from the foundry workers could begin within three to four hours of collection, whilst those from the more distant alkaline accumulator factory were received during the following day.

The following investigations were then made on the urine:

Creatinine.—Creatinine concentration was determined by the alkaline picrate and Lloyd's reagent method of Owen, Iggo, Scandrett, and Stewart (1954).

Urinary Cadmium.—The concentration of cadmium in the urine was determined by the dithizone (diphenylthiocarbazone) method of Smith *et al.* (1955).

Studies on the Protein.—Total protein concentration was measured by a modification of the biuret method of Hiller, McIntosh, and Van Slyke (1927).

PREPARATION FOR ANALYSIS.—Diffusible substances such as urea, salts, and much pigment were removed by dialysing the urine in cellophane sacs overnight against running tap water and subsequently against distilled water for three to four hours. The residue was freeze-dried and the protein was then obtained as a light, water-soluble powder, always associated with a certain amount of brownish pigment, assumed to be urochrome. Attempts to remove this pigment by prolonged dialysis or by precipitating the protein from solution with cold organic solvents were unsuccessful.

Freeze-dried proteins were prepared in a similar manner from the urine of two persons with chronic nephritis but with no known exposure to cadmium, from normal serum, and from serum of a cadmium worker (D1).

PROTEIN-BOUND HEXOSE.—This was measured according to the orcinol (5-methyl resorcinol) procedure of Weimer and Moshin (1953). A 2 : 1 mixture of galactose and mannose was employed as a standard, this ratio approximating to the proportion of hexose found by chromatography.

PROTEIN-BOUND FUCOSE.—The cystine method of Dische and Shettles (1948), with a fucose standard, was followed.

PROTEIN-BOUND SIALIC ACID.—This was determined by the diphenylamine method of Ayala, Moore, and Hess (1951). The standard employed was α_1-glycoprotein (orosomucoid) containing 11·2% sialic acid (kindly supplied by Dr. D. S. Jackson).

ELECTROPHORETIC SEPARATION.—The electrophoretic behaviour of the protein was examined on paper by the ridgepole technique of Durrum (1950), the protein fractions being located with azocarmine B (Plückthun and Götting, 1951) and the profile derived with an EEL "scanner" using a blue filter (maximal absorption 460 mμ).

The proteins were also examined by zone electrophoresis on vertical acetyl cellulose columns (Flodin and Porath, 1954; Campbell and Stone, 1956), in a borate-phosphate buffer medium (0·0115 M, $Na_2B_4O_7$, 0·0155M, NaH_2PO_4, I = 0·05, *p*H 8·6); 150 mg. freeze-dried protein dissolved in buffer and applied to the column was well separated into its component fractions by a potential difference of 220 v. applied for 44 hours. Satisfactory results were achieved by application of higher gradients up to 270 v. for somewhat shorter periods of time. Following electrophoresis, the protein fractions were eluted from the column by buffer and collected in 5 ml. fractions, the concentrations of protein being assessed by the optical density at 280 mμ measured in a Unicam Spectrophotometer S.P. 500.

Those portions of each electrophoretic component having peak absorption values were pooled and the resultant solution checked for homogeneity by paper electrophoresis, before individual preparation for analysis by dialysis and freeze drying.

A few separations were carried out in a similar manner in barbiturate buffer, I = 0·075, *p*H 8·6.

AMINO ACID COMPOSITION.—Each freeze-dried component separated by zone electrophoresis was hydrolysed with 6N.HCl according to Block (1951). The derived amino acids were separated by the two-dimensional paper chromatographic procedure described by Clarkson and Kench (1956), with methanol : water : pyridine (80:20:4 by vol.) and ethyl methyl ketone : *tert*-butanol : water : diethylamine (40 : 40 : 20 : 4 by vol.).

The solution of amino acids in 10% *iso*propanol water was applied directly to the paper.

CARBOHYDRATE CONTENT.—The components were hydrolysed with $N.H_2SO_4$ in sealed tubes (Consden and Stanier, 1952). Descending chromatography with ethyl acetate : pyridine : water (40 : 20 : 40 by vol.) (Jermyn and Isherwood, 1949) was employed and the sugars were detected by spraying with aniline phthalate (Partridge, 1948). The sugars were measured by determination of the areas of spots (Fisher, Parsons, and Holmes, 1949).

ULTRACENTRIFUGE MEASUREMENTS.—Samples of the freeze-dried proteins were dissolved in phosphate-sodium chloride buffer, *p*H 8·0, total ionic strength 0·35 ($KHPO_4$, 0·0044 M, Na_2HPO_4, 0·0652 M, NaCl 0·15 M) and dialysed in cellophane tubes for about 24 hours at 4°C. against a large volume of the same buffer. The refractive increment due to protein in the dialysed solutions was determined with a dipping refractometer (λ = 546 mμ) and the solutions diluted to 1·0 g.

TABLE 1

CONCENTRATIONS OF CADMIUM AND PROTEIN IN THE URINE OF FIVE MEN EXPOSED TO CADMIUM DUST AND FUME

Workman	Exposure (years)	Cadmium (μg./l.)	Protein (g./l.)
D1	14	640	3·2
D2	25	75	1·0
F1	32	310	3·1
F2	37	50	1·2
F3	22	100	2·3

The cadmium values have been corrected to those for a standard urine containing 1·00 g./l. creatinine by the method of Smith and Kench (1957). The protein values are approximate means without correction for urinary concentration.

The concentration of cadmium in normal human urine is <25μg./l.

protein/100 ml. The solutions were then examined in the Svedberg oil-turbine ultracentrifuge in a 12 mm. cell at approximately 250,000 G. Optical observations by the diagonal schlieren method (Philpot, 1938) were photographically recorded on Ilford half-tone panchromatic plates, using a high pressure mercury arc as a light source from which monochromatic light ($\lambda = 546 m\mu$) was isolated by a suitable filter. Distances on the plates were determined with a measuring microscope reading to 0·001 mm. and sedimentation coefficients were computed by the method of Cecil and Ogston (1948).

IMMUNOLOGY.—This was carried out by the tube precipitin method of Oakley and Fulthorpe (1953) using rabbit antiserum prepared against proteins of whole normal human serum.

IMMUNOELECTROPHORESIS.—About 0·05 ml. of a 1% (w/v) solution of protein was subjected to electrophoresis in a 3 mm. deep plate of agar poured from a 2% (w/v) agar solution in glycine-NaCl buffer, *p*H 8·4 (glycine 0·05 M, NaCl 0·05 M, NaOH 0·0025 M, trisodium citrate 0·002 M). The electrophoresis was carried out for a period of 24 hours at 4 C. with a current density of 2mA per cm. width of gel. Rabbit antiserum to whole human plasma was then pipetted into a channel in the gel parallel to the direction of electrophoresis, and the precipitin bands were allowed to develop at 4°C. Photographs of the bands were taken at intervals of seven days for four weeks.

VISCOSITY.—This was measured with an Ostwald viscometer suspended in a water bath at 25°C.

Results

The concentrations of cadmium and protein in the urine from the five men studied are presented in Table 1. Variation from these values was slight. The greatest protein excretion found was 4·2 g./l. in workman D1 accompanied by a cadmium level of 670μg./l. Although of the five men D1 had the shortest period of exposure, he had for a number of years been subjected to abnormally high concentrations of cadmium dust.

Urinary proteins from all five men exhibited electrophoretic behaviour on paper, representative of which is the profile from D1 (Fig. 1a). Five bands were obtained, as with serum proteins under these conditions. The bands were of closely similar electrophoretic mobilities but present in proportions differing from those found in serum. Most noteworthy was the preponderance of globulins, particularly of a component migrating slightly more slowly than α_2-globulin. The pattern for each man was subject to only minor variation throughout the period of study. No changes in these patterns nor in other characteristics of the protein were manifest in urinary specimens allowed to stand in the cold for up to 10 days. The urine of a number of the workmen, showing only a trace of proteinuria, gave electrophoretic patterns with no component of mobility comparable with that of albumin. This is in distinction to the trace proteinurias which are rich in albumin in our control group not exposed to cadmium.

The urinary proteins from all five subjects gave

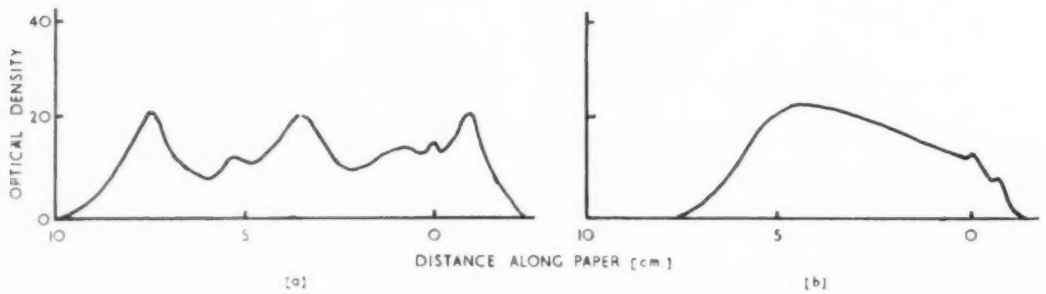

FIG. 1.—Electrophoresis on paper of urinary proteins from the cadmium worker D1: (*a*) Pattern of complete mixture of urinary proteins. (*b*) Heat incoagulable proteins (HIP) separated from the mixture.

The preparation was applied at 0. Separation was carried out in barbiturate buffer I. 0·075, *p*H 8·6, with voltage gradient 3·2 volts/cm. and current density 0·3-0·4 amps/cm., and duration or runs 18 hours. Proteins were stained with azocarmine B and the profile derived with an EEL "scanner" using a blue filter (absorption maximum 460 mμ). Optical density is expressed as readings of the instrument.

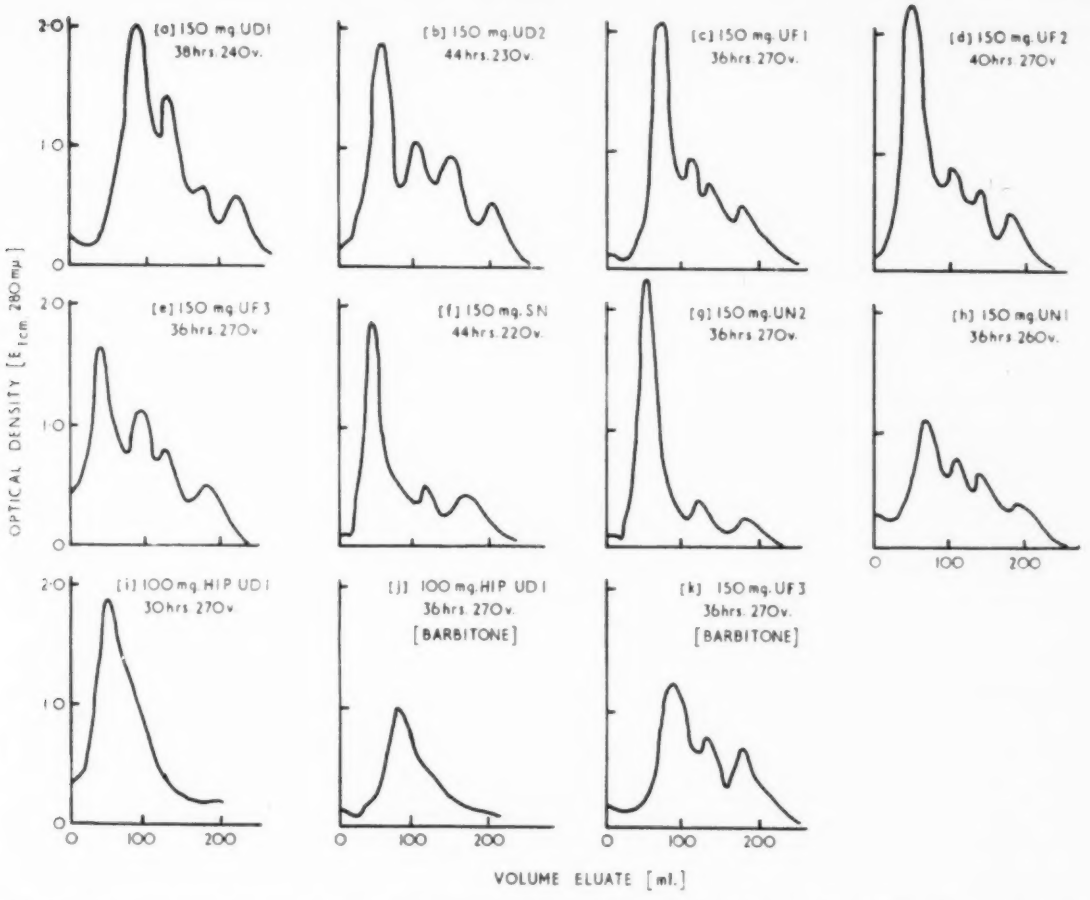

FIG. 2.—Zone electrophoresis of serum and urinary proteins on vertical acetyl cellulose columns. Duration of run in hours, potential gradient in volts; SN = normal serum proteins; HIP = heat incoagulable protein; (g) and (h) are nephritic patients.

Specimens a-i were examined in borate-phosphate medium; j and k in barbiturate buffer.

Ordinates throughout are optical density measurements at 280 mμ of 5 ml. fractions of the eluate from the column; abscissae represent the total volumes of protein solution eluted.

similar patterns when examined by acetyl cellulose column electrophoresis as shown in Fig. 2a-e. Four components only were seen in each case and were enumerated 1-4, having electrophoretic mobilities comparable with serum albumin, α_2-, β-, and γ-globulins. The second fastest fraction of urinary protein appeared to travel with the tail of the first, whilst, under the same conditions, the α-globulins were not separable from normal serum proteins (Fig. 2f) nor from the proteins of one of the nephritic urines (Fig. 2g). The urinary protein from the second nephritic patient exhibited four components (Fig. 2h).

A proportion of the cadmium urinary protein was heat incoagulable, varying when measured as biuret, from 20% in F2 to 25% in D1. This heat incoagulable protein (HIP) moved as a broad band on paper electrophoresis in the region normally occupied by the α_2-globulins (Fig. 1b). Column electrophoresis, however, showed it to be a single asymmetric peak with a mobility slightly greater than that of albumin (Fig. 2i). This increase in mobility in the presence of the borate in the buffer was presumably due to the high carbohydrate content of this protein. The replacement of borate-phosphate with barbitone buffer reduced the mobility (Fig. 2j) without giving a pattern comparable to that on paper. The urinary protein as a whole also retained the general form shown in borate-phosphate buffer when examined in barbitone buffer (Fig. 2k) but the albumin peak was retarded. Addition of HIP to the total urinary protein resulted,

in both buffers on columns of acetyl cellulose, in augmentation of the albumin peak only.

Protein-bound Carbohydrate.—Preliminary experiments showed that the cadmium urinary proteins contained a considerable amount of bound carbohydrate. The nature of this carbohydrate was investigated by paper chromatography of hydrolysates of total urinary protein. By the use of alternative solvent systems all the sugars were shown to be uncontaminated. The results are presented in Table 2.

The distribution of the carbohydrate among the electrophoretic components isolated from the column was investigated by chemical methods. Values for total hexose attached to total protein and to various components are given in Table 3 expressed as protein determined by biuret. Similarly, data for sialic acid bound to the proteins appear in Table 4, and for methylpentoses in Table 5.

Amino Acid Composition.—A total of 13 amino acids was determined by chromatography. For purposes of comparison the eight most accurately measurable were selected and each value expressed as a percentage of the total eight for each component analysed. The amino acids selected were alanine, arginine, aspartic acid, glutamic acid, glycine, histidine, lysine and serine. The results are shown in Table 6.

Sedimentation.—The total urinary proteins of patients D1 and F3 were examined in the ultracentrifuge. Each of these displayed a single, almost symmetrical peak, and the respective sedimentation coefficients were 1·96S and 1·99S (S_{20}, w at 1% protein). The degree of boundary spreading observed was consistent with the low sedimentation coefficient which indicates a molecular weight of the order of 20,000-30,000. The corresponding coefficient of the nephritic urinary protein UN1, was 4·04 which is close to the value for human serum albumin (Kekwick, 1958). These values are in good agreement with previous measurements on similar materials (Kekwick, 1955).

The albumin fraction separated electrophoretically on acetyl cellulose from the urinary protein of patient D1 resolved into two components when

TABLE 2

RELATIVE PROPORTIONS OF MONOSACCHARIDES BOUND TO CADMIUM URINARY PROTEIN, AND TO NEPHRITIC URINARY AND NORMAL SERUM PROTEINS

Nature of Protein	No. of Analyses	Galactose	Glucose	Mannose	Fucose	Ribose
UD1	6	46	4	26	24	—
UD2	6	42	(1)	22	35	—
UF1	5	52	4	19	25	—
UF2	4	44	(2)	18	37	—
UF3	6	35	13	13	25	14
HIP	4	52	—	22	26	—
UN1	6	38	12	19	27	5
UN2	5	36	9	20	30	4
SN	6	30	36	33	—	—
SD1	4	31	36	33	—	—

All figures are expressed as a percentage of the total monosaccharide found in the unfractionated protein and are arithmetic means of the results of the individual analyses. The standard deviation of the readings was 1·78 with 183 d.f.
UD1, etc. — urinary protein from workman D1, etc.
SD1 — serum protein from workman D1.
UN1 and UN2 — urinary protein from two nephritic patients.
SN — normal serum protein.
HIP was prepared from UD1.

TABLE 3

HEXOSE CONTENT OF ELECTROPHORETICALLY SEPARATED COMPONENTS OF CADMIUM URINARY PROTEINS AND NEPHRITIC URINARY AND NORMAL SERUM PROTEINS

Nature of Protein	Total Protein	Component				HIP	HCP
		1	2	3	4		
UD1	76	58	77	29	14	139	11
UD2	98	94	84	32	8	147	10
UF1	86	85	89	41	10	136	13
UF2	67	65	82	36	12	129	9
UF3	86	52	59	42	18	138	12
UN1	31	14	31	22	12	—	—
UN2	33	12	—	24	13	—	—
SN	17	7	—	17	7	—	—
SD1	19	6	—	18	8	—	—

The hexose values were determined by reference to a galactose: mannose (2 : 1) standard and are expressed as mg./g. protein (biuret). Each figure is the mean of two readings.
HIP and HCP = heat incoagulable and heat coagulable fractions of component 1. Other symbols are as in Table 2.

TABLE 4

SIALIC ACID CONTENT OF ELECTROPHORETICALLY SEPARATED PROTEIN COMPONENTS OF CADMIUM WORKMEN AND NEPHRITIC PATIENTS

Nature of Protein	Total Protein	Component				HIP	HCP
		1	2	3	4		
UD1	31	28	23	9	3	61	6
UD2	40	38	31	15	2	65	6
UF1	31	27	26	12	4	57	4
UF2	37	33	30	14	4	69	4
UF3	33	31	24	10	5	70	5
UN1	20	11	17	7	3	—	—
UN2	22	12	—	9	4	—	—
SN	9	4	—	5	2	—	—
SD1	10	4	—	6	2	—	—

The hexose values were determined by reference to a galactose: mannose (2 : 1) standard and are expressed as mg./g. protein (biuret). Each figure is the mean of two readings.
HIP and HCP — heat incoagulable and heat coagulable fractions of component 1. Other symbols are as in Table 2.

TABLE 5

METHYLPENTOSE CONTENT OF ELECTROPHORETICALLY SEPARATED COMPONENTS OF CADMIUM URINARY PROTEINS AND NEPHRITIC URINARY AND NORMAL SERUM PROTEINS

Nature of Protein	Total Protein	Component				HIP	HCP
		1	2	3	4		
UD1	16	14	19	6	2	31	2
UD2	18	17	20	5	2	29	2
UF1	15	16	20	6	3	31	2
UF2	17	16	19	6	3	29	2
UF3	15	14	15	7	3	27	2
UN1	5·3	2·1	4·8	3·7	1·9	—	—
UN2	6·1	2·0	—	3·9	1·7	—	—
SN	1·1	0·3	—	1·2	0·4	—	—

The hexose values were determined by reference to a galactose: mannose (2 : 1) standard and are expressed as mg./g. protein (biuret). Each figure is the mean of two readings.
HIP and HCP — heat incoagulable and heat coagulable fractions of component 1. Other symbols are as in Table 2.

examined in the ultracentrifuge. The slower of these two components appeared to sediment at about the same rate as the whole urinary protein, but the resolution of the two peaks was inadequate to permit the calculation of sedimentation coefficients.

Immunology.—Preliminary investigations of the complete cadmium urinary protein analysed by the precipitin test in agar gel tubes against rabbit antiserum to all normal human serum proteins showed a very complex immunological behaviour. Both serum and nephritic urinary protein also gave a multiplicity of bands but HIP (D1) produced only two major bands. Using smaller tubes (0·2 cm. in diameter) the electrophoretic components from cadmium urinary and serum protein were also tested. In each case only one band was detected. The use of the smaller tubes, employed because of the small quantities of components available, reduced the sensitivity of the technique.

Immunoelectrophoresis.—The pattern of precipitin curves developed after immunoelectrophoresis by the total urinary protein of patient F3 was compared on the same agar gel plate with that of normal human plasma, using a rabbit antiserum against whole human plasma. Six discrete precipitin bands were formed by the cadmium urinary protein, and these spread over the mobility range of albumin to γ-globulin of normal human plasma.

The investigation was not a quantitative one and it is impossible to exclude the possibility that the precipitin bands arose from the presence of serum proteins in the urine in such low concentrations as to be undetected by the ultracentrifuge.

Viscosity.—Total urinary protein from each of the five cadmium workmen was dissolved in isotonic saline and centrifuged free of undissolved protein. Relative viscosities were calculated for solutions containing 5·0 g./100 ml. of dissolved protein, the approximate concentration of the solutions employed. The results are shown in Table 7.

Reducing Sugars.—Each urine sample was tested for reducing sugar with Benedict's reagent. UD1, UF1, UF2 and UF3 persistently showed a trace of reducing sugar, UD2 intermittently, and observations with glucose oxidase ("clinistix") were consistent with the assumption that glucose was responsible. The quantity of glucose present was uniformly less than 0·1 g./100 ml. urine.

Tests for ketone compounds, haemoglobin, and microscopic examination of centrifuged urinary

deposits for crystalline deposits, cells, and casts were consistently negative.

Discussion

From the electrophoretic studies of the biocolloids present in the urine of 11 normal male subjects, Webb *et al.* (1958a) have computed that 24-hour samples of normal urine contained on an average 133 mg. protein. At least seven components were revealed, five of which were similar in electrophoretic mobility to the principal five fractions in serum. A relatively large quantity of protein was present, rich in carbohydrate, which behaved similarly to acid muco-proteins of normal serum. No lipoproteins were detected. Following injection of I^{131}-tagged human serum γ_2-globulins into normal volunteers the iodinated material in the urine exhibited an electrophoretic distribution very similar to that in the serum. The fact that this

TABLE 7

RELATIVE VISCOSITIES OF URINARY PROTEINS OF CADMIUM WORKERS

Source	Relative Viscosity
UD1	1·24
UD2	1·26
UF1	1·25
UF2	1·26
UF3	1·26

Relative viscosity is measured in terms of water = 1·00 and was determined on solutions containing 5·0 g. protein/100 ml. 0·9% NaCl.

TABLE 6

AMINO ACID COMPOSITION OF ELECTROPHORETIC COMPONENTS OF SERUM AND URINARY PROTEINS FROM CADMIUM WORKERS AND NEPHRITIC PATIENTS

Original Protein	No. of Analyses	Component	Arginine	Lysine	Aspartic Acid	Glutamic Acid	Histidine	Glycine	Serine	Alanine
UD1	4	1	8·4	11·7	18·9	20·9	2·6	9·1	10·3	18·1
UD2	4	1	8·1	12·1	16·2	21·3	2·8	10·3	12·2	17·0
UF1	2	1	8·4	13·4	16·2	23·1	2·6	8·2	11·2	16·9
UF2	2	1	8·6	13·3	20·9	23·6	2·8	6·4	9·0	15·4
UF3	7	1	8·0	12·3	16·6	22·4	2·1	9·1	11·9	17·5
UN1	3	1	8·7	14·6	18·3	24·4	2·1	7·1	8·5	16·4
UN2	2	1	7·1	12·1	17·9	24·5	3·0	6·1	7·4	21·7
SN	2	1	8·4	14·7	16·1	26·8	3·3	4·3	6·5	19·8
SD1	3	1	8·1	14·4	17·2	24·6	2·5	4·7	7·6	21·4
Albumin*	—	—	8	17	16	24	4	4	7	(20)
UD1	3	2	9·5	7·5	20·7	17·7	2·4	13·7	13·5	15·0
UD2	3	2	7·9	9·9	17·8	18·8	2·4	14·2	14·4	14·8
UF1	2	2	10·3	9·3	21·4	18·5	2·3	11·3	12·7	14·2
UF2	2	2	9·6	8·9	19·9	18·6	2·7	13·0	13·1	14·2
UF3	2	2	9·9	11·7	19·3	18·0	2·3	13·1	13·8	11·9
UN1	2	2	10·8	8·8	22·3	17·7	3·1	14·2	10·9	12·2
α-globulin*	—	—	7	13	15	31	4	9	10	(12)
UD1	2	3	7·8	8·0	16·1	18·2	2·6	13·9	15·7	17·7
UD2	3	3	9·9	10·9	16·5	18·9	2·8	12·4	16·9	11·6
UF1	2	3	9·7	10·6	16·7	18·3	2·2	13·7	15·1	13·7
UF2	2	3	8·9	10·2	17·4	17·4	2·9	14·0	15·5	13·7
UF3	2	3	10·9	10·3	17·1	17·2	2·9	12·0	15·8	13·8
UN1	2	3	9·0	10·4	18·1	17·2	2·3	12·1	18·4	12·4
UN2	3	3	9·1	8·5	17·3	20·4	2·1	12·0	13·2	17·4
SN	2	3	9·3	10·4	17·8	16·9	2·6	13·2	18·1	11·6
SD1	2	3	9·5	10·8	19·4	20·0	2·0	12·4	13·5	12·4
β-globulin	—	—	6	10	16	21	4	16	15	(12)
UD1	3	4	6·2	6·3	13·9	18·6	2·2	14·7	20·7	17·4
UD2	2	4	7·7	7·5	12·5	18·9	2·1	12·9	21·4	17·0
UF1	2	4	7·6	7·7	13·6	18·6	2·0	13·1	20·8	16·6
UF2	3	4	7·5	9·7	14·5	17·4	2·8	13·1	18·2	16·9
UF3	2	4	8·5	10·5	14·0	16·6	1·9	13·8	22·2	12·5
UN1	2	4	8·6	9·1	14·0	17·9	2·3	16·1	16·7	15·3
UN2	2	4	9·9	8·6	14·3	22·9	2·0	14·0	14·5	11·2
SN	2	4	10·0	8·6	13·3	18·8	3·9	12·7	19·4	13·1
SD1	3	4	9·9	10·4	15·7	18·3	3·0	12·5	17·9	13·7
γ-globulin	—	—	4	12	14	17	4	12	23	(13)
UD1	2	HIP	8·5	11·2	18·0	19·4	2·6	12·9	13·0	14·4
UD2	2	HIP	8·4	10·8	18·9	21·5	2·6	11·2	14·1	12·2
UF1	2	HIP	8·1	10·3	17·1	24·3	3·1	13·9	10·9	12·4
UF2	2	HIP	8·9	9·2	18·7	24·5	2·4	12·9	11·2	12·4
UF3	2	HIP	10·7	9·5	19·4	25·6	2·6	10·2	9·9	12·0
UD2	4	HCP	11·4	17·2	18·6	22·2	2·3	4·5	7·3	16·6
UF1	2	HCP	9·9	15·3	17·9	22·7	4·3	4·6	7·0	18·5
UF2	2	HCP	10·1	15·2	19·2	22·0	3·1	4·9	7·4	18·2
UF3	2	HCP	12·3	13·4	20·4	25·4	1·2	5·0	7·2	15·1
Error†	—	—	0·73	0·79	1·44	1·47	0·56	1·10	1·25	1·28
Variance	—	—	0·45	0·65	1·71	1·98	0·18	1·15	1·55	1·42

The values represent the individual amino acids expressed as a percentage of the total of the eight measured in terms of α-amino nitrogen. Symbols for the protein sources as in Table 2 but HIP and HCP prepared from component 1.

* Data on the normal human serum proteins by ion exchange chromatography (Moore and Stein, 1949).

† Mean difference between 42 pairs of duplicate readings.

urinary globulin had approximately the same relative specific activity as the corresponding serum γ_2-globulin was taken to indicate that the urinary component was closely related in its formation to the corresponding serum fraction, whilst the other proteins in the urine which were not labelled with I^{131} were not derived from γ-globulins.

Physico-chemical studies (Webb *et al.*, 1958b) have failed to distinguish between serum albumin and the albumin fraction of normal urine, but urinary γ_2-globulins are molecules of relatively low molecular weight, 10,600. Rowe (1957) has also observed that urinary albumin of nephritic individuals is identical with the serum albumin of the same individual and with normal serum albumin by immunochemical and osmotic criteria. The average molecular weights calculated for the globulins found in nephrotic urine were invariably less than those of serum albumin and ranged between 36,000 and 65,000.

In the present study of the proteinuria of cadmium workers the quantity of protein excreted was 1·0-3·2 g./l., much in excess of normal. There is a preponderance of low molecular weight proteins in all the fractions into which it can be separated electrophoretically, it being impossible to exclude on the basis of immunological and ultracentrifugal data the presence of traces of normal serum proteins.

The low sedimentation coefficient on ultracentrifugation indicated a uniformly low molecular weight of 20,000-30,000 for all the protein components.

Electrophoretic analysis on paper showed a definite preponderance of urinary globulins, especially α_2-globulin, over urinary albumin (Fig. 1a), much of which could be ascribed to the presence of a heat incoagulable protein migrating in that region (Fig. 1b). Column electrophoresis on acetyl cellulose revealed a relatively higher proportion of urinary albumin, possibly due to a more rapid migration of the heat incoagulable protein in the borate-phosphate buffer (Fig. 2i, j). The hexose, sialic acid, and methylpentose contents of HIP were much higher than for any other protein fraction observed in urine or serum (Tables 3, 4, and 5), whilst corresponding values for urinary albumin were greatly in excess of those found in serum albumin. Fraction 2 of urinary protein from the cadmium workers also contained far more bound carbohydrate than did the urinary protein of nephritic patients. It is probable, therefore, that the urinary albumin fraction was augmented on the acetyl cellulose column by admixture with the heat incoagulable protein, and, indeed, some evidence of two components became apparent on ultracentrifugation.

Amino acid analyses showed that fraction 1 (urinary albumin) was strikingly higher in its content of glycine and serine than serum albumin and, again, a similar difference was seen in the composition of the heat incoagulable protein. Otherwise, no significant differences were apparent between the amino acid composition of corresponding protein fractions separated by column electrophoresis from normal serum, workers' serum, and urine of nephritic patients.

The peculiarity of cadmium proteinuria rests, therefore, upon a preponderance of low molecular weight proteins, some of which are of high carbohydrate content. In contrast to the proteins observed in the urine of normal individuals, of nephritic, as well as of nephrotic patients, fraction 1 (urinary albumin) of cadmium workers is readily distinguishable from serum albumin by its low molecular weight, 20-30,000, whilst the γ fraction, of similar molecular size to this, exceeds that of normal urinary γ_2-globulin, 10,600. It is not known whether the protein originates from the plasma although we have obtained evidence (Wells, Smith, and Kench, unpublished) from studies of incorporation of C^{14} labelled glycine and lysine into the proteins of serum and urine that this may obtain in cadmium poisoned rabbits. It is hoped that by further such studies the site of biochemical action of cadmium may be located.

For a most valuable part of this study we are indebted to Dr. R. A. Kekwick who carried out the ultracentrifugal and immuno-electrophoretic experiments recorded above.

The authors also wish to express their gratitude to Miss I. Dingwall-Fordyce for all her help with statistical aspects of the work. Generous advice and encouragement has been received from Professor R. E. Lane, C.B.E. whose interest in chronic cadmium poisoning prompted this study. We should like to thank Professor A. C. P. Campbell for his support during the later stages of this work. Our thanks are also due to Drs. D. E. Aspin, C. L. Potts, and D. F. S. Flood for allowing us access to the men under their care. The Medical Research Council have generously supported these studies with grants to J.C.S. and A.R.W.

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THE OCTOBER (1960) ISSUE

The October (1960) issue contains the following papers:—

The Relation between Lung Dust and Lung Pathology in Pneumoconiosis. By G. Nagelschmidt.

Diffuse Pleural Mesothelioma and Asbestos Exposure in the North Western Cape Province. By J. C. Wagner, C. A. Sleggs, and Paul Marchand.

Dust Diseases in Dundee Textile Workers. By A. Mair, D. H. Smith, W. A. Wilson, and W. Lockhart.

The Study of Observer Variation in the Radiological Classification of Pneumoconiosis. By J. W. J. Fay and J. R. Ashford.

The Classification of Chest Radiographs for Coalworkers' Pneumoconiosis. By J. R. Ashford.

The Relationship of Byssinosis in the Bacteria and Fungi in the Air of Textile Mills. By Peter Tuffnell.

Experimental Byssinosis. By Peter Tuffnell.

Sickness Absence Among Forestry Workers in the North of Scotland, 1958. By Donald McGregor.

Ecological Factors Affecting Efficiency and Health in Warships. By F. P. Ellis.

Book Reviews.

Index.

A number of copies are still available and may be obtained from the Publishing Manager, British Medical Association, Tavistock Square, W.C.1, price 17*s.* 6*d.*

MISCELLANEA

Grundlagen der Rehabilitation in der Bundesrepublik Deutschland (Fundamentals of Rehabilitation in Federal Germany).*

A Review

By

M. W. GOLDBLATT

This is the 64th monograph in a series issued by the Federal Ministry of Labour on "Work and Health". The titles of some of the preceding volumes are significant as indicating the scope of the project. It is in a sense an extension of the old *Occupation and Health* series issued by the I.L.O. but gives the impression of greater care and expertise. The series includes the following titles: *Rehabilitation in England; Health Education; Rheumatism; Prescribed Occupational Disease; Prognosis of Spinal Column Disease; Immunological Procedures; Productivity, Fatigue, and Health; Practical Physiology of Work; Pocket Book of Occupational Medicine* (reviewed in *Brit. J. industr. Med.* (1959), **16**, 329); *The Problem of Alcoholism.*

The volume under review presents an Introduction, a brief survey of the development and application of measures for rehabilitation in Europe and the United States, a detailed survey of the development of the subject in Federal Germany, brief considerations of congenital abnormalities, of injuries to the spinal column, extremities, and brain of so-called spastics, and of epilepsy in young persons, and of mental defect in the same age-group.

"Young persons", in this context, is, as it is in Britain, inclusive of all persons up to 18 years of age. The volume continues with diseases and defects in adults.

The author deals with war victims, the law relating to accident insurance, insurance to cover personal responsibility and insurance against accident, pension assurances for workers and office workers, workers' pension assurance schemes, public nursing services, the Federal arrangements for employment guidance and unemployment insurance (the word *Arbeitsvermittlung* is taken to signify employment guidance, in the sense of facilitating the placement of an unemployed or physically or mentally defective worker in suitable employment), the extent of rehabilitation measures and the categories to which they apply, and finally, the natural economic gain resulting from rehabilitation schemes.

This volume must be regarded as a guide to the ways and means available for granting the benefits of rehabilitation and, in Federal Germany, therefore, of special interest to doctors, employers, guardians, and vocational advisers in that country.

Although the basic principle of rehabilitation is probably much the same the world over, it is inevitable that differences in practice must appear according to the different systems of law obtaining, the different states of development of social security and health legislation and the different scopes of private, but compulsory, insurance as compared with governmental welfare schemes in a country.

The conception of rehabilitation, set out in the Introduction to the present work, dates back in its widest sense to the French Revolutionary Constitution (1793), Article 21. It may be a revelation to us in Britain to read in this Article:

> "Les secours publics sont une dette sacrée. La société doit la subsistence aux citoyens malheureux, soit en leur procurant du travail, soit en assurant les moyens d'exister à ceux, qui sont hors d'état de travailler".

In 1919 France had 14 rehabilitation and re-training centres and industry had, by law, to employ a quota of about 10% of wounded veterans of the 1914 war. Associations, established by injured and paralysed veterans (1929, 1932) and civilians, furthered the re-incorporation of their members into normal social life and even established re-training centres and protected industries and advisory bureaux for the severely handicapped. However, paper principles and regulations only came to fruition after the 1939 war, when social insurance was reformed to cover long illness and treatment and family allowances for three years, and was extended, in 1946, to include occupational disease and accident. In 1950, tuberculous cases, already constituting almost 33% of pensioners, were incorporated. Private organizations pushed forward the establishment of rehabilitation centres for the tuberculous, including the black-coated and professional classes. This sequence in France shows how long such necessary social services take to become a part of national life; in 1933, there were 7,000 beneficiaries, in 1937, 25,000, and in 1948, 39,000 who received pensions in respect of 66% loss of faculty or earning power.

More modern developments have come about, as they have in Britain, and now there are over 2,000 re-trainees, between 18 and 40 years of age, taken up every year.

French experience has shown that the best results are obtained when re-training is started very early, even during the period of conventional therapy.

It is a source of pride to us in Britain that the measures taken to rehabilitate our wounded, diseased, and injured are regarded as a model all over the world.

*By K. A. Jochheim. (Pp. 203). Stuttgart: Georg Thieme Verlag. 1958.

In the United States, the scale on which rehabilitation is operated is enormous. In 1954-55 some 60,000 handicapped persons were prepared for entry into jobs, their mean age being 34 years; 60% of these disabled arose from disease, 28% from accident, and 12% from abnormalities since birth. Although the Federal Government contributes something like £8m. to £10m. a year to the rehabilitation schemes and the States about £13m. a year, emphasis is placed on the fact that the beneficiaries are " not receiving Charity but Opportunity " and this is substantiated by the claim that the national outlay is amortized within three years.

It is an important point to remember that in the United States, there is no legal obligation on employers to employ re-trained handicapped workers. The process, therefore, starts with a choice of occupation by the handicapped person; then follows re-training in conformity with the condition of the trainee; thereafter, there follows a trial period in the chosen workplace. Once taken into a fully-paid job, the employee hardly receives, or expects, special consideration. Individual cases of more severe disabilities may be taken into private undertakings designed to utilize the residual faculty of such persons.

The state of mind which informs rehabilitation schemes in the U.S.A. must be seen against a background of very little State provision for illness. The law is concerned with ill-provided, handicapped children, blind persons, and old people; insurance provides for old age pensions, orphaned, and unemployed persons, and for occupational accidents and disease. Compulsory insurance to cover employers' liability is a feature of all industry, and there are agencies connected with the 1950 Social Security Act which, in case of need, can supplement the benefits of unemployment insurance in, notably, chronic disease and accidents. There are 100 centres for rehabilitation in the U.S.A. and, in addition, hospitals are taking it up in increasing measure.

In Federal Germany, Jochheim's own summary of the stages of the rehabilitation process is as follows: (*a*) Primary medical or surgical treatment; (*b*) Physiotherapy on classical lines; (*c*) Provision of prostheses; (*d*) Occupational therapy and training; (*e*) Return to former occupation. If unsatisfactory, re-training in a fresh trade; (*f*) Provision of work in a normal or " protected " factory or workshop according to legal definition of " protected "; (*g*) After-care and observation to assess success or failure.

There are eight establishments taking 165 males and 61 females, where young persons, resident or ambulatory, can receive schooling of one kind or another, according to the nature of the defects, with specialist medical cooperation. The curricula include work in metal, paper, paste-board, wood, and textiles, commercial training, higher academic studies, stenography, and telephony.

The author gives the names of firms employing about 800 severely injured persons.

In spite of the fact that the volume is designed principally for German professional people, it will reward colleagues in other countries, living in other systems of social and political structure. It is written in a matter-of-fact way and requires no deep knowledge of the language.

United States Public Health Service

The strengthening of the United States Public Health Service's programme to protect the health of workers through the creation of a new Division of Occupational Health was announced recently by the Surgeon General.

The new Division replaces the Occupational Health Programme and is designed to place greater emphasis on all types of environmental health hazards. Dr. Harold J. Magnuson has been named Chief of the new Division.

The Division will carry out an expanded research programme directed at developing better techniques, materials, and equipment for use in the prevention, diagnosis, and treatment of occupational disease. Research efforts will be intensified in toxicology and in related fields of clinical medicine, engineering, chemistry, and physics.

Emphasis will be placed on the training of personnel in occupational medicine and nursing and in industrial hygiene. The Division will work with academic institutions and other groups to help develop the necessary professional resources.

The Division will also be responsible for stimulating effective community and industrial efforts to supply occupational health services.

Harwell Radiation Protection Course

The fourth Advanced Course in "The Principles of Radiation Protection" will be held in the Harwell Reactor School from April 19 to July 18, 1961.

The course, which comprises lectures, practical work, demonstrations, and visits, is intended for graduates or persons of graduate standard either entering or already working in the field of radiological health and safety. The course will cover a wide field of fundamental background knowledge and will deal with principles rather than with particular techniques. A high academic standard is set, but since few academic courses cover all the necessary subjects, the course of lectures will begin with first principles, and will not require previous specialized knowledge.

Some of the lectures will be given by the staff of the school, but the majority will be delivered by experts from Harwell and other U.K.A.E.A. establishments. It is also hoped, as on previous courses, to have lectures from experts from the Medical Research Council, the Agricultural Research Council, the Central Electricity Generating Board, the Institute of Cancer Research, the Radiological Protection Service, and the Ministry of Housing and Local Government.

Application forms and further details can be obtained from The Manager, The Reactor School, Atomic Energy Research Establishment, Harwell, Berkshire.

BOOK REVIEWS

Modern Trends in Occupational Health. Edited by R. S. F. Schilling. (Pp. ix + 313; 46 figures. 67*s*. 6*d*.) London: Butterworth. 1960.

The publication of this work under Richard Schilling's editorship is something of a landmark in the post-war literature of occupational health; there has been nothing quite like it since Merewether's three volumes in 1954 from the same publisher.

This single volume does not aim at the comprehensive survey attempted by Merewether, but chooses to explore in considerable depth some novel or recent developments. It is therefore a selective book, reflecting equally its editor's wide interests and his contributors' special talents. Its purchase can be recommended with confidence to postgraduate students of industrial medicine, and to all practitioners, physicians, nurses, and engineers engaged in the search for better occupational health. Personnel officers and management generally would also benefit by selective reading.

Twenty-five contributors have produced 21 chapters. The list of contributors is among the most distinguished to be assembled in this country; the authors are all British with one notable exception, Ross McFarland of Harvard.

Because Schilling's choice has been so personal, and only for this reason, your reviewer feels justified in making a personal choice of the chapters offered. For his own interest, for what that is worth, the following are the outstanding chapters: "The Toxicology of Metals" (E. Browning); "Morale and the Size of the Working Group" (R. W. Revans); "Machine Design and Human Engineering" (R. McFarland); "Noise" (W. Burns), and "The Value of Routine Medical Examinations" (L. G. Norman). The latter chapter should be read by every doctor and personnel officer engaged whole or part-time in industry.

Schilling's own chapter with which the book commences deals with "The Measurement of Health", by epidemiological techniques and makes an excellent introduction.

"Radiation Hazards" (W. Court Brown and R. Doll) and protection against them (E. E. Smith), are two chapters placed early in the book. They point the importance of this relatively new subject for industrial physicians, and both are unusually well written and lucid. Smith places particular emphasis on the much wider control which radioactive substances will demand of industry and transportation in the decades ahead. Court Brown and Doll have interesting observations to make on the non-specific ageing of irradiated populations.

J. C. Gilson has produced, as expected, a classic chapter of only 28 pages on "Industrial Pulmonary Disease" and has contributed extensively (with C. B. McKerrow) to the preceding chapter "Lung Function and its Measurement in Industrial Pulmonary Disease". These two chapters in the order in which they appear form a most useful section.

Further on in the text G. M. Carstairs, "Mental Illness and Work", distinguishes clearly between psychotic disease and minor psychiatric disorder in working populations. The portion of his text which deals with the prevention of psychiatric illness is good too, although all readers may not share his enthusiasm for Field-Marshal Montgomery's memoirs!

Carstairs' contribution is aptly preceded by A. G. P. Elliott writing on "Vocational Psychology"; this is a most interesting chapter also. One is astonished to learn that despite the outflow of trained psychologists from our university departments, no more than 30 are to be found in British industry, and that even in the U.S.A. the number is not more than 100; one would like to know the comparable position in the U.S.S.R.

Heron, as might be anticipated, has written on "Ageing and Employment" and has done it very well. The age-group 55-64 will increase by 30% as between 1954 and 1979, a mere quarter of a century. His comments therefore on the problem of enforced retirement at a set chronological age are pertinent.

Space alone does not permit more than mention of the remaining chapters and they are in no way less important than those quoted. At least in this review they should all be listed: they are as follows: "Toxicity Testing" (J. M. Barnes); "Safety in the Use of Pesticides" (J. M. Barnes and E. F. Edson); "Occupational Cancer" (A. L. Walpole and M. H. C. Williams); "Prevention of Accidents" (R. Bramley-Harker); "The Treatment of Injuries at Work" (J. P. Bull); "Occupational Health Services in Smaller Work Places in Britain" (Lord Taylor); "Industrial Law: Trends and Prospects" (W. Mansfield Cooper).

The whole work concludes, most suitably, with a chapter from R. E. Lane on "The Teaching of Occupational Health".

As an indication of the standard of scholarship invariably maintained throughout this book, there is a total of some 890 references. References are quoted separately at the end of each chapter rather than at the end of the book as a whole, with the single and nice exception of "Industrial Law", where they appear, as in legal commentaries, at the foot of the page.

The index is compiled with care and accuracy. One suspects that much of the hard work in compiling the reference sections and the index has fallen, inevitably, on the shoulders of those privileged to work in Schilling's department at the London School of Hygiene and Tropical Medicine, and the editor gives due thanks to them in his introduction.

The book is easy to read on a 5-in. line, set in Times Roman type face and printed on a non-gloss paper. The pictures are good, too.

OWEN MCGIRR

A Symposium on Industrial Pulmonary Diseases. Edited by E. J. King and C. M. Fletcher. (Pp. viii + 273; 98 figures. 32*s*.) London: J. and A. Churchill. 1960.

This is a valuable contribution to existing knowledge on a subject which has attracted much intensive research especially during the last decade. It comprises the 21 papers contributed at a symposium held at the Postgraduate Medical School of London in September, 1957 and March, 1958, and, by virtue of the coordinated arrangement of the papers, it presents a clear statement of the present position of thought and practice in this field in Britain.

Coalworkers' pneumoconiosis occupies a prominent place in many of the papers and a few deal specifically with it. This is to be expected: for it is the most prevalent disease due to dust and the object of much research carried out in Britain and sponsored by the Medical Research Council and the National Coal Board as well as other bodies.

In a general survey of industrial pulmonary diseases in Britain, A. Meiklejohn reviews some of the statistics available and indicates the need for special investigations into the significance of variations in prevalence. The pathology of the pneumoconioses is dealt with by J. Gough and A. G. Heppleston and special reference is made to characteristics of the disease found in workers in coal, asbestos, and talc. The reaction of the lung to dust is studied by E. J. King and C. V. Harrison in a brief paper on experimental evidence in favour of the hypothesis that massive fibrosis in miners is due to a combination of dust and tuberculous infection. The physical process of deposition of dust in the lungs is described by C. N. Davies in a lucid examination of the process and its results. G. Nagelschmidt reviews the theories on the origin of the silicotic nodule and the experimental evidence underlying them. Ultrahistological work by French observers points to changes in the mitochondria and the death of the cell apparently resulting from the action of silica fume, the test substance. Radiology occupies three papers: G. Simon writes on problems in taking and reading chest radiographs; C. M. Fletcher recapitulates the radiological diagnosis of pneumoconiosis and discusses the differential diagnosis; P. J. Chapman, on radiography in the field, gives details of equipment and techniques required for a high and consistent standard. In epidemiology of coalworkers' pneumoconiosis A. L. Cochrane refers to research work carried out by the Pneumoconiosis Research Unit in South Wales. In this area too the Miners' Chest Diseases Treatment Centre gives hospital treatment for advanced cases of the disease.

Normal lung function and its measurement is discussed by P. Hugh-Jones. The disturbance of pulmonary function in industrial pulmonary disease is discussed by J. C. Gilson; an important and significant distinction is made between pneumoconioses fitting the International Labour Office radiographic classification and those which do not fit; other conditions considered are byssinosis, cadmium smelters' emphysema, and late effects of acute exposure to irritant gases. The general principles in the use of pulmonary function tests in epidemiological work are described by C. B. McKerrow.

The pneumoconioses of tin-miners, granite workers and china clay workers in Cornwall are described by L. W. Hale. A. I. G. McLaughlin writes on iron and other radio-opaque dusts encountered in several occupations. A. John Robertson describes the processes of tin smelting and gives an illustration of a radiograph of a tin smelter's lungs. The epidemiology of byssinosis is described by R. S. F. Schilling.

Other notable contributions are studies on bronchitis in industry by I. T. T. Higgins; occupational lung cancer by Richard Doll; and a well illustrated article on rheumatoid disease and pneumoconiosis by Anthony Caplan. The final paper on the prevention of silicosis, by Donald Hunter, contains the essential principles of this most important approach to all the problems of pulmonary disease due to dust.

The volume is well presented by the publishers; a relevant bibliography accompanies each paper; and there is an excellent index.

E. L. MIDDLETON

Guide to Hygiene and Sanitation in Aviation. (Pp. 51; 18 figures, 3*s*. 6*d*.) Geneva: World Health Organization. London: H.M.S.O.

This report is based on that of the W.H.O. Expert Committee on Hygiene and Sanitation in Aviation, 1959. It is a considerable improvement on previous publications of this nature including that of the U.S. Department of Health, Education, and Welfare, whose handbook on Sanitation of Airlines (1953) is now seriously outdated.

This well written handbook deals with three abiding principles, which hold true on the ground and in the air.

(a) Food and water and the utensils or vessels used for services must be free from both living organisms of disease and toxic substances of any origin.

(b) Persons must be kept from contact with infected wastes, particularly human wastes.

(c) Persons must be kept from contact with infected insects, rodents, or other vectors of disease.

Accordingly, subsections are devoted to and specific recommendations made on, the sanitation of water, drinking fountains, disinfection of water, aircraft water systems, water service outlets, water hoses, water carts, food preparation, food handlers, building and premises for food preparation, cleansing and germicidal treatment, food sanitation on aircraft, toilet waste disposal, sewage disposal, refuse disposal, aircraft toilet fluids, and finally insect control, mosquito proofing, fly control, and rodent control. This is a comprehensive list of subjects for a small handbook and the matters raised are dealt with firmly, accurately for the greater part, and with clarity.

There is still no attempt to lay down international standards for aircraft toilet fluids. Economics aside, some international agreement on this subject is urgently required. Aircraft in this day and age may be handled by a large number of countries on an agency basis, so

that toilet fluids and antiseptic powders (all vastly different and even chemically non-compatible) are poured willy-nilly into the toilet systems. Eventually this potent brew of germicides may be poured down the sewage system of a small tropical or sub-tropical airport's sewage farm in the middle of the dry season, with disastrous results on its biological working.

Although written with such small airports in underdeveloped lands in mind (as well as the large international airfields), this otherwise excellent account fails to mention the sort of practical difficulties outlined above.

OWEN MCGIRR

Data Sheets on Dust Collectors. By British Steel Castings Research Association. (Pp. 38 + Index; illustrated. 30*s*.) Sheffield. 1960.

This compilation of data sheets relating to the performance of commercial dust collectors available in this country is one that will be extremely useful to industrial hygienists and works engineers.

Each data sheet states the type classification of the dust collector, and a sketch illustrates the principle of operation. The pressure drop, and where applicable, water usage, are stated and examples of installations with volume of air handled are quoted.

An endeavour has been made to provide data on collection efficiency, in terms of particle size but for some products this information has not been available. However, a series of collection efficiency curves for the basic types of dust collectors are given, so that the performance of a particular collector can be predicted to some extent.

The variation in the availability of manufacturers' data, however, indicates the desirability of the formulation of a standard testing procedure, and for users to require the results of such tests as an essential part of the specification of the equipment they are purchasing.

D. E. HICKISH

Air Sampling Instruments for Evaluation of Atmospheric Contaminants: American Conference of Governmental Industrial Hygienists, Cincinnati (1960). (Illustrated. $7.50.) Ohio, U.S.A. 1960.

The United States of America leads the world in industrial hygiene, so one looks somewhat humbly at her latest production in this field. This is a descriptive manual of air sampling instruments which are readily available in America. It deals comprehensively with instruments for gases, vapours, mists, fumes, and dusts.

The book opens with a group of seven papers which discuss in general terms the ways in which air sampling should be done, and how instruments are devised to meet these requirements as nearly as possible. There is a first-rate opening paper by Silverman, giving a systematic review of the methods used for sampling and analysing air contaminants. This is followed by an enthusiastic contribution on "home-assembled" instruments by Setterlind, who apparently can make anything with a syringe, a piece of plywood, and a couple of elastic bands. The remaining opening papers are dull.

The introductory papers are followed by full technical descriptions of over 100 different air samplers, ranging from a $1.00 "do-it-yourself" dust sampler to a magnificent $7,100 machine which produces a continuous record of the concentration of three different gases simultaneously. As the information on each sampler has been compiled from descriptions provided by manufacturers and designers, it is inevitably somewhat uneven; but there has been a considerable effort to give a systematic account of the uses and operating principles of each instrument, together with a description of the performance, construction, and operating instructions. Notes are also given on the maintenance and calibration of the instruments. Especially helpful is the information on where each instrument can be bought or who designed it.

This unusual book, with its rather unattractive print and loose-leaf paper-covered back, gives a false impression of being poorly finished. It would have been well worth an extra dollar or so to have a stiff cover. Even so, it manages to stand erect when supported on one side by Patty's "Industrial Hygiene" and on the other by Drinker and Hatch's "Industrial Dust"! I recommend it to every industrial hygienist.

S. A. ROACH

Individuelle Vorbeugungsmassnahmen gegen Berufliche Augenschadigungen. By A. S. Schafranowa. (Pp. 132; 29 figures. DM. 14.20.) Berlin: VEB Verlag Volk und Gesundheit. 1959.

This book, a German translation from the original Russian edition, gives a comprehensive review of the protective appliances used in the U.S.S.R.

The first chapter deals with the anatomy of the eye and the basic principles of optics are discussed. The second chapter gives the general principles for construction of individual eye protections. The protective appliances are designed to meet the following three hazards: (1) Protection of the eye against small particles flying off from machines at high speed; (2) Radiation, infra-red and ultra-violet light; (3) Chemical agents. The author also describes an appliance for testing the protective value of the lenses supplied in goggles and masks. A steel ball in an adjustable tube is held by an electro-magnet. The ball is released and it falls on the lens to be tested from various heights.

The types of protective goggles which are used in the U.S.S.R. are enumerated and filter absorption curves are given. Masks which protect the whole face are also described.

The author gives a very full Russian bibliography. All the references most of which are pre-war (1930-1941) are taken from Russian journals, especially the Soviet Ophthalmological Journal. There are several references dealing with the recent work (1953, 1954 and 1955) on protection of the eye in the U.S.S.R., but the author gives no references from international ophthalmological literature, nor from international industrial medicine.

JOSEPH MINTON

Human Relations: An Outline of Human Relationships. By Dr. Eustace Chesser with a Preface by Sir Cyril Burt. (Pp. 446. 25*s*.) London: Wm. Heinemann. 1959.

"The general aim of this book is to investigate the conditions necessary to make the most of our lives," writes Dr. Chesser, and as his subject is the relationships between individuals from the moment of conception to the grave (and even beyond) nobody can accuse him of not trying. The work is addressed primarily to the intelligent layman and written in the lucid popular style of which the author is a past master. Doubtless many medical men would derive considerable benefit from it but, since an almost disproportionate amount of space is concerned not merely with normal sexual relationships but also with the grossly abnormal, some may find themselves almost as surprised as the lay reader, although whether the latter is likely to be either aided or edified by the detailed descriptions of cases of flagellation and fetishism must remain a matter of opinion. The single chapter entitled "Man in the Machine Age" which deals with industrial relations emphasizes the drawbacks of overcentralization, the working group as a source of social satisfactions, and the importance of individual differences and abilities; it occupies 16 pages. If it contains little with which the industrial psychologist or medical officer could find fault, it is unlikely that he will find anything novel.

J. A. C. BROWN

Books Received

(Review in a later issue is not precluded by notice here of books recently received.)

Disc Lesions and Other Invertebral Derangements Treated by Manipulation, Traction and Other Conservative Methods. By E. J. Crisp. (Pp. viii + 158; 48 figures. 15*s*.) Edinburgh and London: Livingstone. 1960.

Post-basic Nursing Education Programmes for Foreign Students: Report of a Conference, Geneva, October 1959. [Wld Hlth Org. techn. Rep. Ser. No. 199.] (Pp. 47. 3*s*. 6*d*.) Geneva: World Health Organization. 1960.

Casualty Services and their Setting: A Study in Medical Care. (Pp. viii + 135; 3 plates, 10 tables. 7*s*. 6*d*.) London: Oxford University Press (Published for the Nuffield Provincial Hospitals Trust). 1960.

Lavorazioni che Espongono All'Azione di Acido Cianidrico E Composti del Cianogeno. By S. Fumasoni and M. Rafanelli. (Pp. 94; 12 tables.) Milan: Tipo-Litografia I.N.A.I.L. 1960.

Ethiopia in Review, Nos. 11 and 12, Winter and Spring 1960. (Pp. 20; illustrated.) London: Embassy of Ethiopia. 1960.

Expert Committee on Tuberculosis: Seventh Report. [Wld Hlth Org. techn. Rep. Ser. No. 195.] (Pp. 19. 1*s*. 9*d*.) Geneva: World Health Organization. 1960.

Evaluation of Industrial Disability, 2nd edition. By Packard Thurber. (Pp. 63; 78 figures. 10*s*.) New York: Oxford University Press. 1960.

Radiations in Industry: How They Affect You. (Pp. 95; illustrated. 4*s*.) London: Trades Union Congress. 1960.

Occupational Health Review, Vol. 12, No. 2. (Pp. 21; illustrated.) London: Occupational Health Division, Department of National Health and Welfare. 1960.

Health and Hormones. By A. Stuart Mason. (Pp. 200; illustrated. 4*s*.) Middlesex: Penguin Books. 1960.

Occupational Diseases and Industrial Medicine. By Rutherford T. Johnstone and Seward E. Miller. (Pp. vii + 482; illustrated. 84*s*.) Philadelphia and London: Saunders. 1960.

Chemicals in Food and in Farm Produce: Their Harmful Effects. By Franklin Bicknell. (Pp. 192. 12*s*. 6*d*.) London: Faber and Faber. 1960.

Child Guidance Centres. [Wld Hlth Org. Monograph Ser. No. 40.] (Pp. 133. 20*s*.) Geneva: World Health Organization. 1960.

Tobacco Manufacturers' Standing Committee. Report for Year Ended May 31, 1960. (Pp. 11.) London: Campbell-Johnson. 1960.

Verhandlungen der Deutschen Gesellschaft für Arbeitsschutz, Band 6. Kongress für Arbeitsschutz und Arbeitsmedizin, 1959. By E. Mager, P. E. Rosenberger and O. Schneider. (Pp. xii + 336; 86 figures, 13 tables. DM. 30.) Darmstadt: Dietrich Steinkopff. 1960.

Studies of Ageing Within the Conditions of Modern Industry. Growing Old in a Mechanized World: The Human Problem of a Technical Revolution. By F. Le Gros Clark. (Pp. 145; 3 tables. 7*s*. 6*d*.) London: The Nuffield Foundation. 1960.

Klinische Grundlagen der sechsundvierzig meldepflichtigen Berufskrankheiten. By Ernst. W. Baader. (Pp. xii + 479; 69 figures, 12 coloured plates. DM. 58.) Berlin: Urban and Schwarzenberg. 1960.

Report on the Health of the Royal Air Force and Women's Services of the Royal Air Force for the Year, 1957. (Pp. 54; 21 tables, 10 charts.) London: Air Ministry. 1960.

Proceedings of the Pneumoconiosis Conference, held at the University of Witwatersrand, Johannesburg, 1959. Edited by A. J. Orenstein. (Pp. xvi + 632; illustrated. 120*s*.) London: Churchill. 1960.

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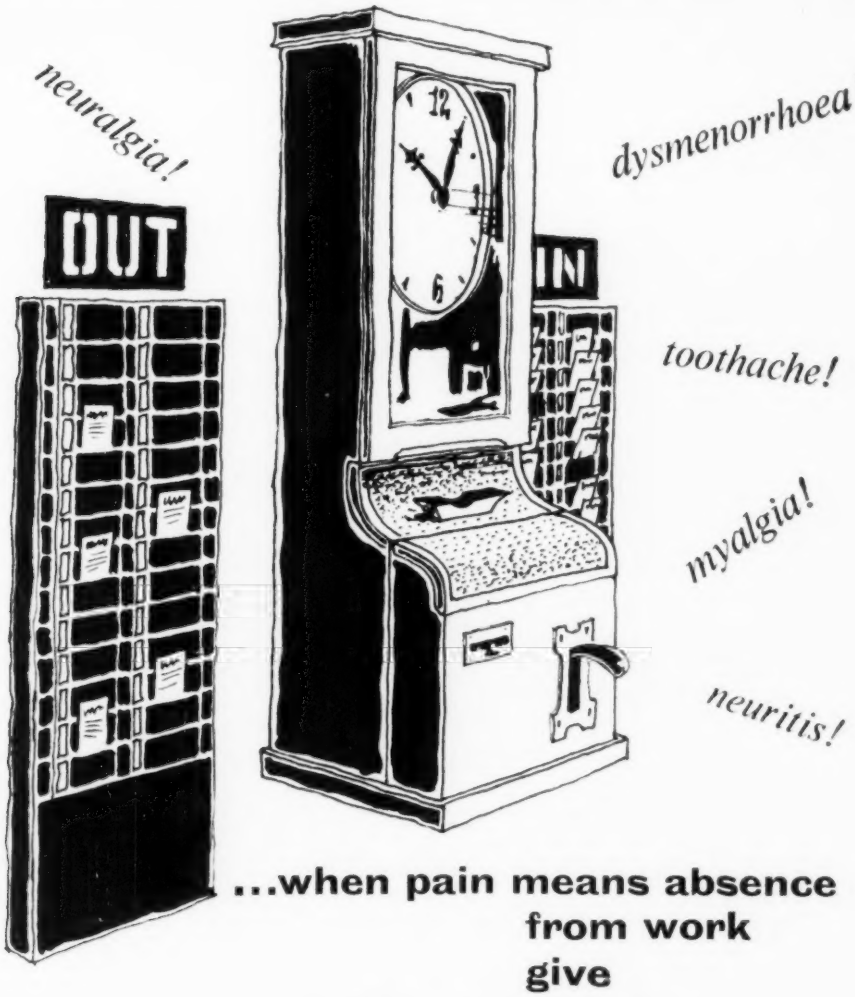

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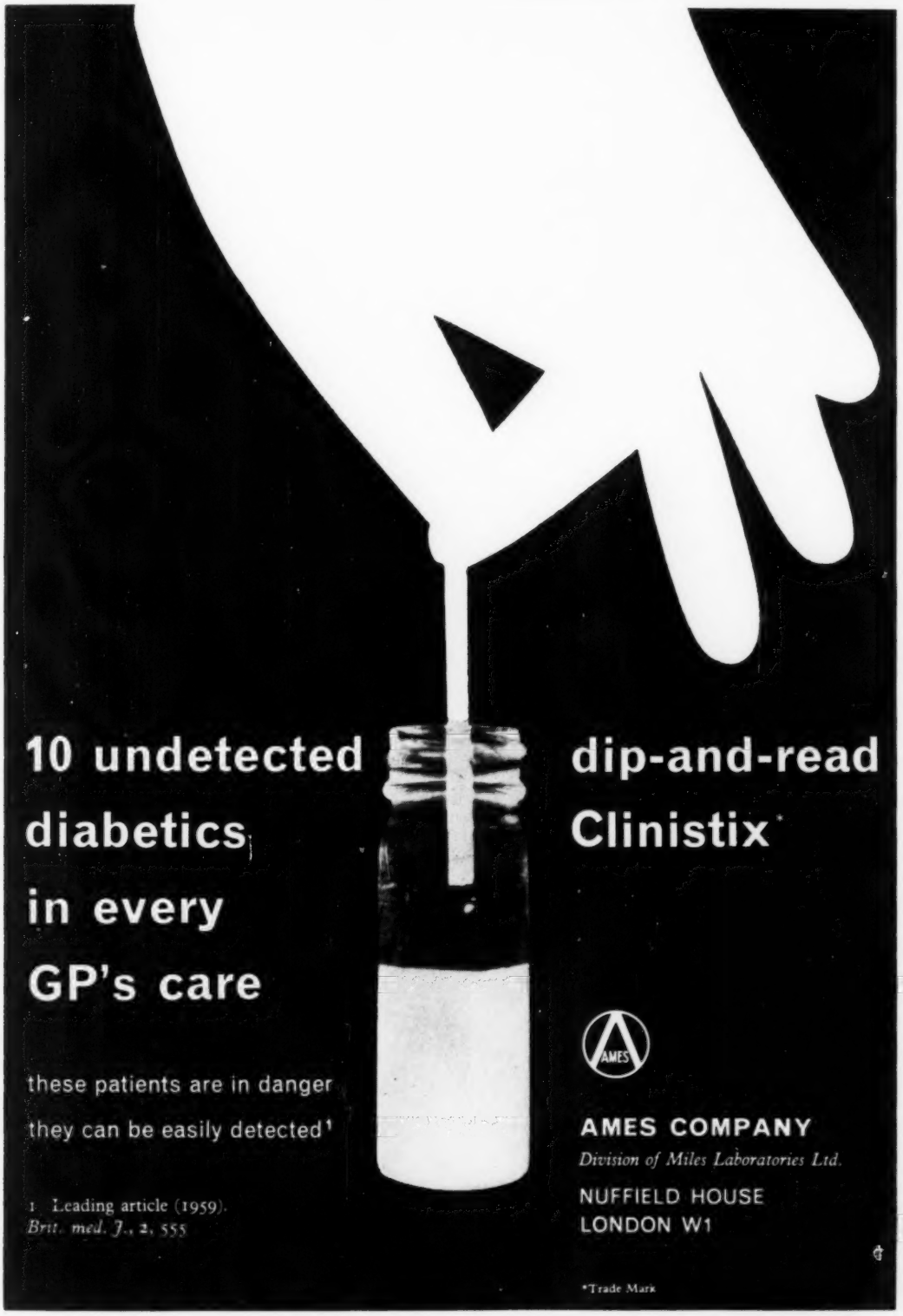
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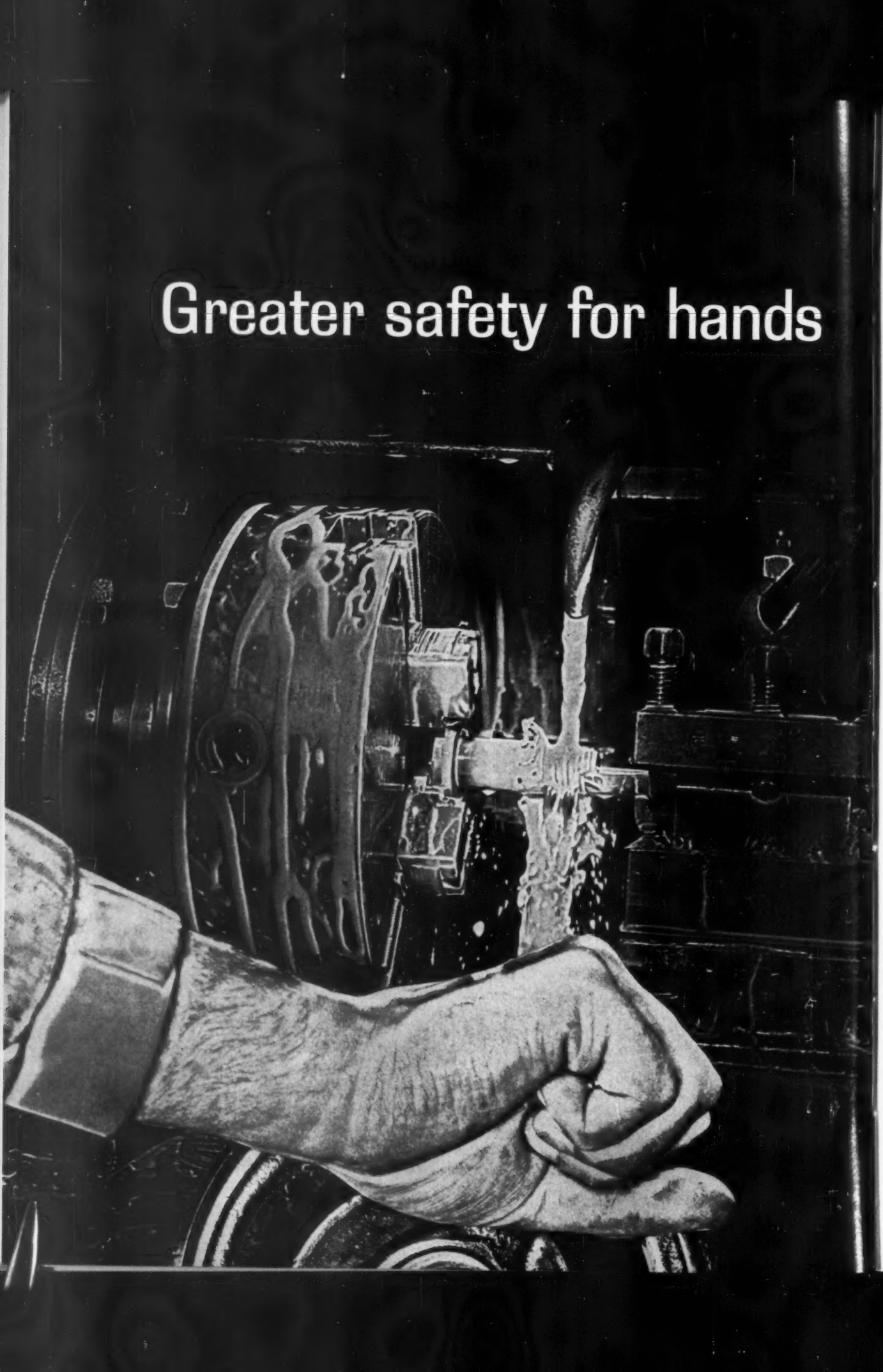

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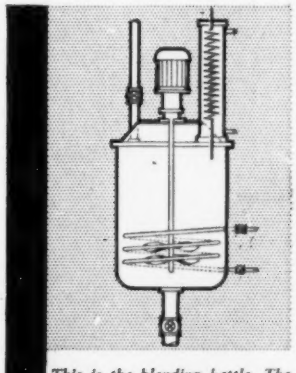

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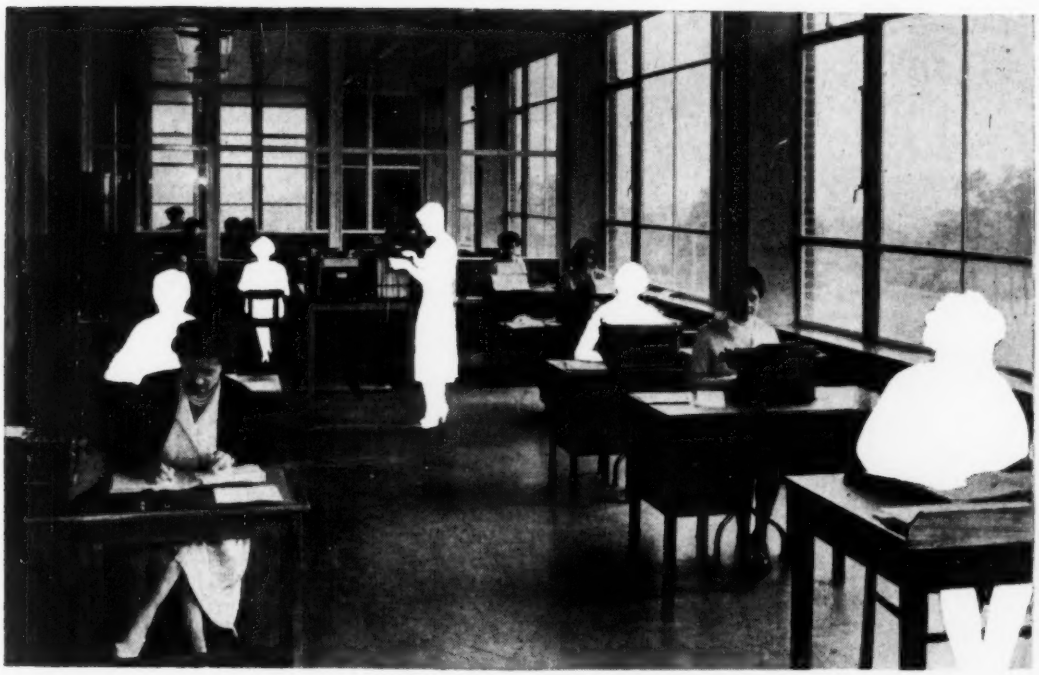

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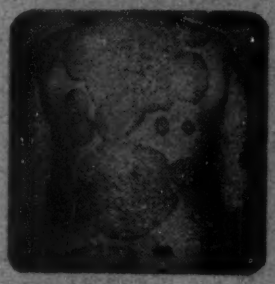
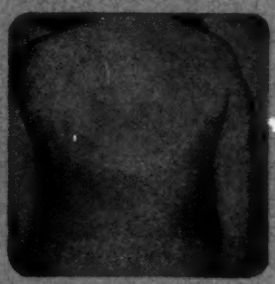

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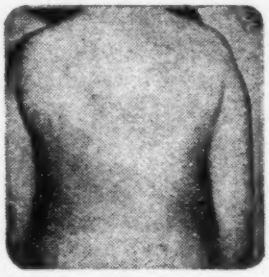

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